THE

AËRONAUTICAL JOURNAL.

(FOUNDED 1897 in succession to the ANNUAL REPORTS).

THE ORGAN OF THE ROYAL AËRONAUTICAL SOCIETY.

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All communications should be addressed to the Editor.

No. 89. MAY, 1918. VOL. XXII.

Notices of the Royal Aëronautical Society.

The Name of the Society.

At the "Wilbur Wright" Lecture, on June 25th, Sir William Weir, Secretary of State for the Air Ministry, announced from the chair that His Majesty had been graciously pleased to confer on the Society the dignity of being known, henceforth, as "The Royal Aëronautical Society"; in recognition of the Society's work in the interest of the nation.

The Annual Holidays.

These offices will be closed from Monday, August 5th, for the annual holidays and will re-open on Monday, August 26th.

Obituary.

It is with great regret that we record the death of Mr. Bertram George Cooper, as a consequence of a flying accident on Saturday, June 8th, 1918. Mr. Cooper joined the Society in 1910. He was one of the original Associate Fellows and was this year made a Fellow of the Society. From July, 1912, to December, 1916, he was the Secretary of the Society. In this capacity he made many friends and was beyond question conscientious and painstaking in the discharge of his duties. On retiring from the secretaryship Mr. Cooper was elected a Member of Council. Mr. Cooper was a man with many good qualities of both head and heart, of great natural ability, and of a simple and retiring nature. He had a genuine enthusiasm for aeronautics and with no definite scientific training had by private study acquired a real and catholic knowledge of the subject in its many aspects. On retiring from the secretaryship he joined the firm of Mr. Griffith Brewer—the Aeronautical Instrument Co. There can be no doubt of his qualifications for this work. As an experimentalist in mechanical work Mr. Cooper showed some approach to genius, for he was fertile in ideas and deft of hand. Early this year he was appointed to a responsible post on the Technical Department of the Air Ministry and his friends had every justification for their belief that this was the opening of a long and useful career in the public service. Mr. Cooper, who was 36, was a widower and leaves a son of three years of age. Mr. Cooper figured in the New Year honours as the recipient of the M.B.E., and was the

holder of the bronze medal of this Society for research work on the subject of insect flight.

We regret to record the death of Major Herbert Musgrave, D.S.O., R.E., killed in action. Major Musgrave joined the Society in 1913 and was elected an Associate Fellow the following year.

Honours and Awards.

The following distinctions have been conferred on members of the Society :—

The Duke of Atholl to be Knight of the Thistle.
Lieut.-Col. J. C. Porte, R.A.F., to be C.M.G.
Lieut.-Col. R. K. Bagnall Wild, R.A.F., to be C.M.G.
Sir W. R. Lawrence to be G.C.V.O.
Sir Horace Darwin, LL.D., to be K.B.E.
Frederick Handley Page to be C.B.E.
Henry White Smith to be C.B.E.
Capt. F. S. Barnwell to be O.B.E.
Reginald Ormsby Cary to be O.B.E.
Capt. G. de Havilland to be O.B.E.
Miss Hilda Hudson to be O.B.E.

The Editor will be much obliged if readers of the Journal, who are interested in timber, will send him a list of any trade or colloquial names of timbers used in the manufacture of aircraft. There is considerable divergence in nomenclature, and it would be extremely interesting were a proper comparative table drawn up showing the differences which exist in different localities.

THE ANNUAL GENERAL MEETING, 1918.

The Annual General Meeting of the Aëronautical Society of Great Britain was held on Tuesday, June 18th, at 5.0 p.m., at the Offices of the Society, 7, Albemarle Street, London, W.1. The Chairman of Council, Major-General R. M. Ruck, C.B., C.M.G., R.E., presided.

The SECRETARY read the notice convening the meeting.

The CHAIRMAN asked that the meeting approve the postponement until that afternoon of the date of the Annual General Meeting which should, under Rule 11, have been held before the 31st March. The authorised date was a very inconvenient one which did not fit in with the working of the Society.

The postponement was approved.

Miss Phoebe Hudson, Major Low, R.A.F., and Mr. Ormsby were appointed scrutineers of the ballot for the Council.

The CHAIRMAN, in introducing the Annual Report of the Council and the Balance Sheet for 1917, said:—

Before beginning the business of the meeting I wish to say a few words about the great loss which has been sustained by the Society in the death of Mr. B. G. Cooper.

Mr. Cooper was for nearly eight years a member of the Council and for over four years Secretary to the Society, during which time I was closely associated with him and can state from personal experience that the Society could not have had a more devoted official. Whatever action he took or opinion he expressed, it was always with the object of furthering the interests of the Society. He took a special interest in the scientific and educational aspects of aeronautics and was always urging the necessity for maintaining the prestige of the Society in these particulars. He was a most conscientious secretary, and I am sure all members of the Society with whom he was brought in contact had the greatest respect for him. He resigned the secretaryship, having received the offer of an appointment at the Air Ministry, which he thought it his duty to accept. It is evident that his services were greatly appreciated by the Air Ministry, for he received an honorary distinction and quite recently an important appointment. As to his death, all that need be said is that his life was given to further the interests of the national cause and the development of science, the subject on which he had concentrated the efforts of his valuable life.

The Council of the Society have expressed their regret and sympathy with Mr. Cooper's relatives, and I am sure all members will be anxious to endorse this action.

The Annual Report of the Council has been circulated to all members and I hope will be considered satisfactory. Generally speaking, I think it will be agreed that it is so.

There has been a gratifying increase in membership and also in the funds of the Society, which are in a sound financial condition.

The activities of the Society have been considerable, notwithstanding the exceptional difficulties due to the war. I wish to direct special attention to the work which is being done by members of the Society in connection with Government Committees during the past year. I can state from personal knowledge that the status and valuable work of the Society are fully acknowledged by the Government authorities, a particularly gratifying example of which is the consent of the Secretary of State for the Air Ministry to preside at our Annual Wilbur

Wright lecture next week, on which occasion Dr. Durand, the distinguished scientific American aeronautical expert, has kindly consented to give a lecture.

Another committee which I would specially refer to is the Technical Terms Committee, presided over by Colonel O'Gorman. This Committee consists, in addition to representatives of the Aeronautical Society, of representatives of the Air Council, War Office, Admiralty, Patent Office, Meteorological Office, the Advisory Committee for Aeronautics, Royal Aero Club and the Society of British Aircraft Constructors. They have also been assisted by the National American Advisory Committee for Aeronautics, and the results are most valuable.

Whilst all this points to the continued progress of the Society I think I ought to refer to some difficulties which have been experienced, more especially in securing an adequate attendance of members of the Council except in certain cases. It is quite realised how difficult it is under present circumstances for the members to attend more frequently, but if this cannot be done it throws the management to a great extent on the Chairman and the Secretariat, which I am sure is not a satisfactory arrangement in the long run. I hope, therefore, it may be possible to revise the activities of the sub-committees to a greater extent and that in future the bulk of the work will be done by this means. In saying this I do not reflect in any way on the work of the Secretary and staff, in fact, I am sure that all members appreciate thoroughly the improvement in membership and financial position which is due in considerable measure to Mr. Faraday and his assistants. I am rather speaking of the general policy which should be pursued by the Society with regard to its future organisation and activities. There is a great deal of most useful work to be done in developing the scientific, technical and educational aspects of aeronautics, and I am convinced that this can only be effected satisfactorily by the combined efforts of the Council and the members of the Society.

Sir MACKENZIE CHALMERS moved the adoption of the Report. It was, he thought, more than satisfactory, and those responsible for the working of the Society were to be congratulated on the record of work done and the great success achieved. He would like to draw attention to two points. One was the very necessary work of co-ordinating much of the scientific work done on behalf of the Civil Aerial Transport Committee. The second point was the desirability of sympathetic co-operation with similar societies to their own in the United States.

Mr. BAIRSTOW said that the first point was receiving attention from the proper authorities.

The SECRETARY said that the Society was in regular correspondence with the various American aeronautical organisations.

Sir MACKENZIE CHALMERS said that was very satisfactory.

Mr. C. G. GREY seconded the adoption of the report. He associated himself entirely with the congratulatory remarks of the mover of the resolution.

The Report was unanimously approved.

Mr. R. BORLASE MATTHEWS moved the adoption of the Accounts and Balance Sheet. It was a great pleasure to learn of the satisfactory financial position of the Society.

Mr. F. BRAMWELL seconded, and the accounts were unanimously approved.

The scrutineers announced the result of the ballot, having found that on a count of the votes received the following were elected to the Council:—

Major-General Ruck.	Lieut.-Col. R. K. Bagnall Wild.
Mr. L. Bairstow.	Mr. H. White Smith.
Dr. T. E. Stanton.	Dr. R. Mullineux Walmsley.
Major A. R. Low.	Mr. F. H. Bramwell.

The Chairman having been thanked for presiding, the meeting terminated.

AERONAUTICAL SOCIETY OF GREAT BRITAIN.

Council's Report, 1917—1918.

The past year has been one of continued success and a development in the work and influence of the Society. As will subsequently appear the membership has continued to grow, while fresh opportunities for useful work are continually being offered as open to the Society's activities.

Membership.

In January, 1917, the total membership of the Society stood at 343; the acting membership (*i.e.*, those whose subscriptions were less than three years in arrears) was 297. Owing to the outbreak of war and the impossibility of carrying on the activities of the Society at the time, for some considerable period the membership had shown a decline and the Council viewed this with some anxiety in view of the increasing demands made upon the Society's funds.

Towards the close of 1916, however, the Council decided to attempt to renew these activities, and it was clearly necessary that the Society should keep abreast of the progress that was being made in aeronautics through the agency of the Flying Services, the Manufacturers, and the National Advisory Committee on Aeronautics, with the assistance of the National Physical Laboratory and the Royal Aircraft Factory. The association of the Aëronautical Society with that of the recently formed Society of British Aircraft Constructors also made it desirable that an effort should be made to increase the membership amongst the manufacturers.

After a good deal of consideration the Council decided that it was essential to adopt a forward policy, to remove the offices and library to more suitable premises, to institute an up-to-date series of lectures, to improve the Journal, to endeavour in every way to increase the membership, and to engage a competent staff sufficient in number to deal with the amount of work anticipated.

From subsequent experience, however, it has been apparent that the enterprising policy followed has been amply justified, the Society now numbers 772 members and is still rapidly increasing, so that it may be confidently predicted that before the next annual report is presented the number will be considerably in excess of 1,000. While expressing their satisfaction with the progress thus made, the Council view with even greater pleasure the quality of the new adherents to the Society's ranks, including, as they do, many of those whose names have in recent years been prominent in both the administrative or engineering branches of aeronautics in this country and the United States of America. On the technical side of the Society, the improvement has been specially marked. The number of Fellows and Associate Fellows has increased from 79 to 226. As these are the official qualifications for an aeronautical engineer, all concerned may be congratulated upon the fact that in substance as well as in name the Society is now the recognised professional institution for this branch of engineering. Although it would be manifestly impossible during the present crisis of public affairs to require the test of examination for candidates admitted to these grades of membership the Council have in all cases rigorously exacted a high standard of qualification in making election to it.

In regard to the student members of the Society the increase per cent. has been larger than in any other class of member. As these represent the Fellows and Associate Fellows of the future, the progress made in this particular is very gratifying.

The Civil Aerial Transport Committee.

One of the most important events in the year as far as the Society is concerned was the action of the Government in forming the Civil Aerial Transport Committee to report upon the possibilities of civil aerial transport after the war. This Committee was appointed in May last with Lord Northcliffe as chairman. The terms of reference were very wide and included aeronautical research and education in addition to many other matters in which the Society is specially interested. In fact the discussions of this Committee have had such a bearing upon the activities of the Society and upon those of the Society of British Aircraft Constructors that development in those directions has been deferred until after the Committee has made its report, an event which appears to be likely to occur in the near future.

It may be mentioned that in addition to Lord Northcliffe, the chairman, and the acting chairman, Major Baird, D.S.O., M.P., Under-Secretary of State of the Air Ministry, all the chairmen of the special sub-committees (five in number), Lord Sydenham, Major-General Ruck, Mr. White Smith, Mr. H. G. Wells and Colonel O'Gorman, and many of the members of the Civil Aerial Transport Committee are also members of the Aëronautical Society, so that the Society is very fully represented.

Meetings.

During the early spring of the present year the excellent series of lectures provided for the members was largely interrupted by public necessity. Many of the papers offered had on account of the subjects with which they dealt to be withdrawn, as in the opinion of the authorities it was prudent to withhold such matters from publication lest they prove of service to the public enemy. In spite of this, however, many interesting and valuable papers were given and the Council desire to acknowledge the kindness of Major-General W. S. Brancker, Sir Richard Glazebrook, F.R.S. (Director of the National Physical Laboratory), Sir Napier Shaw, F.R.S. (Director of the Meteorological Office), Major Lyons, F.R.S., Lieutenant-Colonel O'Gorman, C.B., Lieutenant-Colonel R. K. Bagnall Wild, A.I.D., Major Bertram Hopkinson, F.R.S., Sir Henry Fowler (Assistant Director of Equipment to the Air Ministry), Professor Groom, and Mr. G. Holt Thomas for their support in consenting to preside at the fortnightly meetings.

The Council also offer their most cordial thanks to Captain F. M. Green, Mr. W. H. Dines, F.R.S., Mr. J. R. Pannell, Dr. A. P. Thurston, Mr. R. Borlase Matthews, Mr. W. H. Barling, Messrs. W. W. and A. G. Hackett, and Mr. W. E. John for the series of admirable lectures placed before the Society.

Popular Lecture.

A second popular lecture was arranged in the Central Hall, Westminster, on June 21st, 1917, when Colonel Lord Montagu of Beaulieu lectured on "The World's Air Routes and their Regulation." The meeting was an unqualified success, over 2,500 persons being present. General R. M. Ruck, C.B., C.M.G., R.E., the Chairman of the Society, presided.

Juvenile Lecture.

On January 2nd a new departure was made in the syllabus of the Society in that a Juvenile Lecture was given to the children of members and friends.

An attendance of more than 500 young people listened to an excellent lecture on "The Aeroplane," kindly delivered by Dr. A. P. Thurston. The Council desire to acknowledge the assistance they received from Mr. Smith Woodward of the Natural History Museum, Mr. Edwards of the Northampton Polytechnic, Mr. A. F. Houlberg, Captain Maddick of the Scala Theatre, Messrs. Pathe Frere, Messrs. Calthrops, Ltd., Messrs. Handley Page, Ltd., and Dr. R. Mullineux Walmsley, in providing and arranging slides, cinematograph, models and experiments.

Educational Lectures.

Acting on the suggestion of the Air Ministry courses of educational lectures similar to those delivered at Hendon last year through the generosity of Mr. Handley Page have been delivered in other principal centres of the aircraft industry, and these lectures, principally intended for the workpeople engaged in the industry, were very largely attended, the average attendance being over 500 per lecture. Courses of ten lectures each were given at Birmingham, Hammersmith, the Royal Aircraft Factory, South Farnborough, Bristol, Southampton, Peterborough, Leeds, Norwich, Lincoln and Coventry.

The thanks of the Society are due to the National Advisory Committee of Aeronautics and to the Air Ministry for the permission given for members of the staff of the National Physical Laboratory and for officers of the Flying Services respectively to give lectures. The Council confess their great indebtedness to Captain F. M. Green, Mr. E. F. Relf, Mr. A. Fage, Captain F. S. Barnwell, Captain Aston, Commander C. C. Turner, Lieutenant-Colonel J. N. Fletcher, Major G. I. Taylor, Professor Duffield, Mr. R. O. Boswall, Captain J. S. Irving, Mr. J. D. North, Mr. F. H. Bramwell, Commander W. Lockwood Marsh and Captain Fleming Williams, who so ably delivered the lectures.

The Council also desire to acknowledge the great kindness of Sir Henry Fowler, Major H. Grinsted and Mr. Greenley of the Royal Aircraft Factory, the Austin Motor Co., Ltd., of Birmingham, Messrs. A. V. Roe, Ltd., Dr. A. Hill of the University College of Southampton, Messrs. Gwynnes, Ltd., of Hammersmith, the British and Colonial Aeroplane Co., the University of Bristol, the Blackburn Aeroplane and Motor Co., the University of Leeds, the Siddeley-Deasy Motor Car Co., Ltd., of Coventry, Messrs. Boulton and Paul, Ltd., of Norwich, Messrs. Ruston, Proctor and Co., Ltd., of Lincoln, and Messrs. Frederick Sage and Co., Ltd., of Peterborough, in assisting with the arrangements for the lectures.

The thanks of the Council are again due to Mr. Handley Page for arranging a second course of educational lectures at Hendon.

The Technical Terms Committee.

Recognising the importance of standardising the terms used in relation to aircraft, the Council last July appointed a strong sub-committee to deal with this subject. Other bodies interested were invited to send representatives, and the Sub-Committee, as finally constituted, consisted of the following:—Colonel O'Gorman, Mr. L. Bairstow, F.R.S., Colonel Briggs, R.N., Mr. B. G. Cooper, Lieutenant-Commander A. R. Low, R.N.V.R., and Mr. R. Borlase Matthews (Aëronautical Society); Messrs. W. Cannell, R. K. Pierson and R. Seabrook (Society of British Aircraft Constructors); Mr. C. G. Grey (Royal Aero Club); Commander Cave Brown Cave, R.N., Major Clarson, Captain Ewen, Lieutenant-Colonel Landon and Captain Myers (Air Ministry); Lieutenant A. C. Day (War Office and Admiralty); Mr. A. S. A. Ormsby (Patent Office); Mr. F. J. Selby (Advisory Committee on Aeronautics); and Sir Napier Shaw (Meteorological Office). On occasion the Sub-Committee has been much helped

from outside and is grateful particularly to the National American Advisory Committee on Aeronautics for its sympathetic assistance. The American Missions in Europe have on occasion been present at the meetings in the persons of Dr. Durand, Mr. Coker Clarkson and Mr. Ericson, and are now permanently represented on the Committee by Mr. W. G. Renals. In view of the risk of overlapping of this important work, by arrangement with the Engineering Standards Committee, the Technical Terms Sub-Committee also acts as the Nomenclature Committee (Aircraft Section) of the British Engineering Standards Committee. The Sub-Committee has already examined and classified several hundreds of terms. It is dealing with the matter in an exhaustive manner and due acknowledgments should be made for much patient and laborious work in important undertakings on the part of all those who have co-operated. The Council desire especially to mention the services of Lieutenant-Colonel O'Gorman, who undertook the onerous and responsible duty of Chairman of the Committee.

Patents Bill.

The Society took part in an important conference on the rights of inventors under the New Patents Bill, convened by the Institution of Mechanical Engineers, the Society being represented by Mr. Griffith Brewer, Mr. A. Pickles and the Secretary. The informal opinion of the conference was duly taken and negotiations are still pending.

Engineering Training.

On the initiative of Mr. A. E. Berriman, a member of the Council of this Society, a conference of all the bodies in this country interested in engineering education was summoned at the Institution of Civil Engineers on October 25th, the representatives of this Society being Dr. R. Mullineux Walmsley and Mr. B. G. Cooper. An influential committee was formed with the object of co-ordinating this branch of technical education, and to carry into effect the decision of the conference.

Department of Scientific and Industrial Research.

The Council has in common with the Society of British Aircraft Constructors taken the initial steps towards forming a Research Association in connection with this department.

The Library.

The Council desire to express their grateful acknowledgments to Mrs. McAlister, who has re-catalogued and arranged the whole of the Library. A large amount of binding has been done and many new books added. Every attempt is being made to bring the Library thoroughly up to date and as complete as possible. The Council desire to acknowledge gifts of books and prints from Mr. Charles Bright, Colonel de Villamil, Mr. Hatton Turner, and others. The Council also desire to acknowledge the courtesy displayed to this Society by the Society of Automotive Engineers in the United States in arranging with them for a supply of American aeronautical publications.

The Journal.

After running for exactly twenty years as a quarterly, the AËRONAUTICAL JOURNAL is now being issued as a monthly, and it is hoped that members will appreciate this attempt to give them earlier access to the recorded proceedings of the Society. The price of the Journal to non-members has been largely increased, and the Council desire to point out that members of the Society now receive in the form of publications considerably more than the nominal amount of their subscription, and this quite apart from the other advantages of the Society.

Branches.

Negotiations are in progress for the establishment of graduate branches of the Society at South Farnborough, Hendon, Glasgow and Manchester.

Abstracts.

The need of a complete abstract of the world's Press and scientific journals dealing with aeronautical subjects, has long been felt. The Council are glad to announce that in consequence of arrangements which have been completed and with the valued assistance of the War Office and the National Physical Laboratory the Society will shortly be in a position to publish complete abstracts for the benefit of aeronautical science and industry in this country.

Administration.

The Council desire to acknowledge the very willing and able assistance which they have received from their Secretary (Mr. W. Barnard Faraday) and the staff in carrying out the programme of work sketched out above, together with the general secretarial duties of the Society.

Miss Phyllis Boyd, who was appointed Assistant Secretary in December, 1916, resigned her position for private reasons in September. The Council desire to acknowledge Miss Boyd's efficient services. After a little delay Miss Olive St. Barbe was appointed to the vacancy and has rendered valuable assistance to the Society.

Finance.

The financial position of the Society is satisfactory and continues to improve, but the Council strongly urge the necessity of a further increase in membership. Much work remains to be done which can only be accomplished by the greater income which will follow the enlargement of the Society. The credit balance of the Society on December 31st, 1917, was £1,409 5s. 2d., an improvement of £704 15s. 8d. over the previous year, notwithstanding a large increase in necessary expenditure. On March 31st, 1918, the credit balance of the Society stood at £2,499 2s. 8d. The Society has been in a position to convert the whole of the sums received as entrance fees and life compositions in accordance with the view of the Hon. Auditors that their money should be treated as capital and not as income. Investment was made in July of funds belonging to the Society amounting to £750 in War Loan, and in "Tank Week" in London on March 9th, 1918, the Society invested a further £100 in National War Bonds. Further sums are awaiting investment. In addition to this the various trust funds which the Society administers stand at nearly £2,000. The Council are glad to announce that the lack of punctuality in payment of subscriptions, to which they drew attention in their last report, has been very much mitigated and that the number of overdue subscriptions is comparatively small.

The Hon. Officials.

The Council desire to express their most cordial thanks to the Hon. Auditors, Messrs. Jas. E. Ward and Co., for their services in auditing the books of the Society, and to Mr. B. Woodward, the Hon. Solicitor, who has advised them throughout the year.

AERIAL

(The Aeronautical

GENERAL INCOME AND EXPENDITURE ACCOUNT

Expenditure.

	£ s. d.	£ s. d.
To Office Rental, Lighting and Insurance	299 17 2	
,, Salaries	385 13 0	
,, Exhibitions and General Meetings	210 4 0	
,, Printing, Stationery, etc.	151 3 7	
,, Postages, Messengers, etc.	101 9 10	
,, Library Expenditure	29 9 6	
,, Office Expenses	84 16 8	
		1,262 13 9
,, Removal Expenses, Repairs and Cost of Lease ...		36 19 3
,, Journals, Pamphlets, etc., Balance		111 13 6
,, Balance being excess of Income over Expenditure ...		321 2 10
		£1,732 9 4

BALANCE SHEET,

Liabilities.

	£ s. d.	£ s. d.
Nominal Capital	1,000 0 0	
Divided into 20 Shares of 1/- each and 999 Shares of £1 each.		
Capital issued and called up:—		
11 Shares issued and fully paid up		0 11 0
Sundry Creditors		198 4 9
Subscriptions paid in advance		32 11 0
Reserves and Apportionments		5 5 0
Reserve Fund:—		
Entrance Fees and Life Compositions of present Members as at 31st December, 1916	819 12 0	
Receipts during 1917	383 13 0	
		1,203 5 0
Revenue Account:—		
Surplus 1916 Balance	704 9 4	
Excess of Income over Expenditure, 1917, exclusive of Entrance Fees	321 2 10	
	1,025 12 2	
Less—Transfer to Reserve Fund	819 12 0	
		206 0 2
		£1,645 16 11

SCIENCE, LTD.

Society of Great Britain).

FROM 31st DECEMBER, 1916, TO 31st DECEMBER, 1917.

Income.

	£	s.	d.
By Annual Subscriptions	954	17	6
,, Interest on Deposit Account	0	18	6
,, Dividend on War Loan	18	15	0
,, Donations	757	18	4
	£1,732	9	4

31st DECEMBER, 1917.

Assets.

	£	s.	d.	£	s.	d.
Cash at Bank—Coutts and Co.				201	5	4
Cash in hand				47	6	7
Investments:—						
£750 of 5% War Loan				709	6	4
Office Furniture, Printed Books, Bindings, Stationery, Old Prints, etc., as per last Balance Sheet ...	88	0	0			
Additions during year	219	11	8			
				307	11	8
Stock of Journals, etc., at Society and with Society's Printers				10	0	0
Sundry Debtors, including Subscriptions owing				352	16	0
Reserves for amounts paid in advance				17	11	0
				£1,645	16	11

I beg to report that all my requirements have been complied with by the Directors and Officers of the Company, and that in my opinion the foregoing Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Company's affairs, according to the best of my information, and the explanations given to me, and as shown by the books of the Company.

(Signed) JAMES E. WARD, *Chartered Accountant*,
London and Birmingham.

11th April, 1918.

TIMBER: ITS IDENTIFICATION AND MECHANICAL PROPERTIES.

BY W. H. BARLING, A.R.C.SC., B.SC., ASSOC. FELLOW.

In this paper I propose to bring before you a broad outline of our knowledge of the subject, not from the point of view of a botanist, but purely from the point of view of an engineer.

Although in ancient, and in fact during all time, timber has been extensively used for constructional purposes, our knowledge of it is comparatively small, whilst the subject itself is very extensive.

The reason for these facts is not hard to find. Unfortunately the physicist has not in general had to deal with timber in the progress of physical research, as he has with metals; and the questions which concern the engineer are not in general those with which the botanist deals.

There has been comparatively little incentive for engineers to do much work on timber, as before the advent of the aeroplane its application was limited to unimportant parts, except in America and the Colonies, where the cost of metal parts is high. A considerable amount of information has in recent years been published by the American Government Forestry Department; the Government of New South Wales, Australia, have also published a considerable amount of data on Australian timbers.

Research on timber and also the application of such research is very much more difficult than that for isotropic materials such as metals.

The field to be covered is also much more extensive. Whereas there may be about 100 metals and their compounds in fairly general use, there are at least 1,000 different kinds of wood on the commercial market in everyday use.

It is obvious that the subject of the identification of timber is of fundamental importance. The engineer deals with cut-up timber. He has no bark, leaves, or buds to guide him to a conclusion as to the name of the timber with which he deals, whereas it is these features upon which the botanist mainly depends for his decision; most botanists are unable to identify a piece of cut-up timber presented to them as this involves very specialised knowledge of a narrow branch of the great subject of botany.

The identification of cut-up timber is of importance to the engineer whether he be engaged on inspection or research, and it is a subject upon which there is particularly little knowledge.

The author proposes to spend some little time on this point this evening; he desires to introduce a very fascinating and profitable hobby to those who may not have met it before—the study of the structure of timber.

Fig. 1* shows the structure of a piece of Norway spruce. The diagram in the top left hand corner indicates the wood as ordinarily seen, whereas the larger diagram shows the structure magnified 100 times.

This is a typical example of one of the simplest woods.

The wood consists of the long vertical tubes which are made up in sections with the scarf joints as seen towards the lower left hand corner of the diagram.

These tubes are called "trachieds," and have on their walls circular holes called "pits," which are closed by a delicate membrane. Slits and spiral lines may also appear on the walls of the trachieds.

These trachieds are not all of equal size, and this variation in size gives rise to

* Figs. 1, 2, 3, and 4 are taken by kind permission from "Timbers and How to Know Them," by Dr. Hartig and Dr. Somerville. This book is highly recommended.

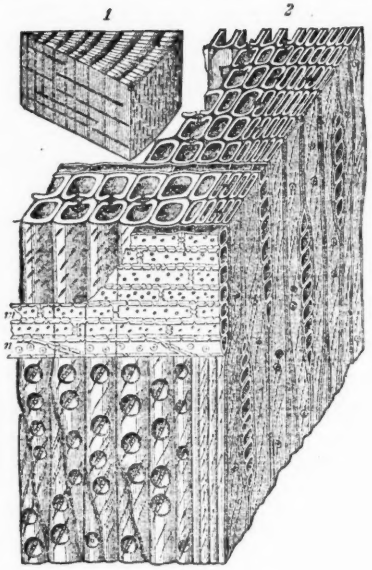


FIG. 1

1. A piece of wood from the Norway Spruce which has been deprived of its rind. Natural size.

2. A portion taken from the nearest upper outside angle of Fig. 1. The figure represents the wood towards the outside of an annual ring, magnified 100 times.

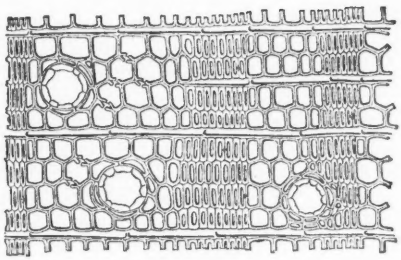


FIG. 2.

Transverse section through narrow-ringed, thin-walled wood of the Norway Spruce, showing three resin-ducts, the walls of which appear too thin in the figure. Magnified 100 times.

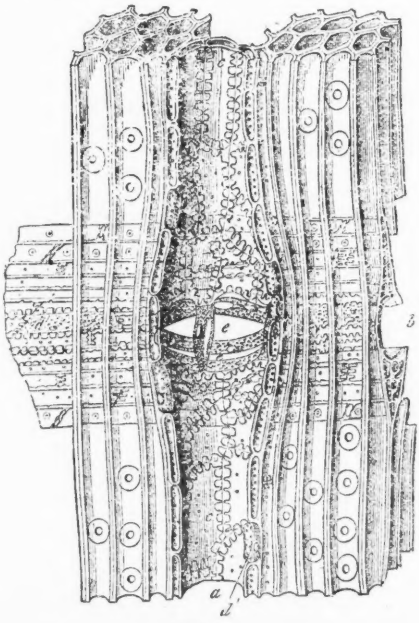


FIG. 3.

Point where two resin-ducts cross in the wood of the Norway Spruce. Magnified 100 times.

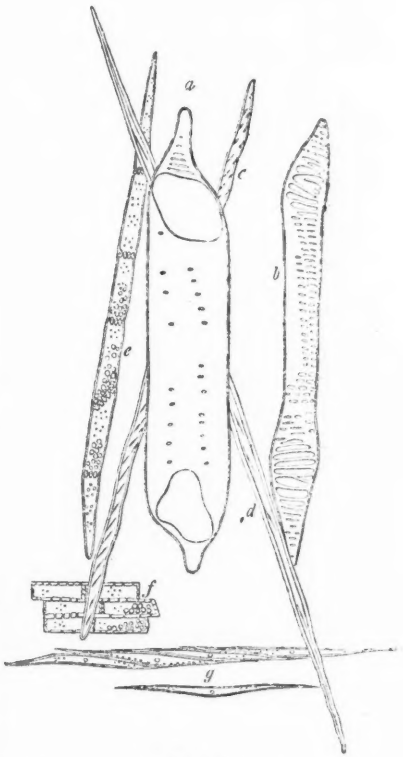


FIG. 4.

Organs of the Beech, isolated by maceration. Magnified 100 times. *a*. Segment of a vessel with wide lumen; the transverse septa have been completely absorbed. *b*. A smaller vessel-segment, the transverse septa of which have been broken through in a ladder-like manner. *c*. A Tracheide, whose bordered pits have been rendered unrecognisable by maceration. *d*. A sclerenchymatous fibre. *e*. Wood-Parenchyma, some cells of which contain starch grains. *f*. Some cells from a thin Medullary Ray. *g*. Some cells from the middle of broad Medullary Rays.

the periodic colour differences called "annual rings," which are apparent when a cross section of timber is examined by the naked eye.

The variation in size is due to the changes in the seasons of the year. The timber formed during the spring consists of large trachieds almost circular, whilst those formed during the autumn are very narrow in a radial direction.

In addition there are brick shaped channels running radially, *i.e.*, longitudinally in the diagram. These are the medullary rays.

On the walls of the medullary rays are pits very much smaller than those on the trachieds. The inner wall of the medullary ray may have tooth-like projections, and this is a useful feature of identification of certain woods.

Fig. 2 shows a cross section of the wood perpendicular to the axes of the trachieds. The medullary ray sections can also be seen as channels running radially.

The large holes seen amongst the cross sections of the trachieds are resin ducts; there are three in the diagram. Fig. 3 shows cross section of intersecting resin ducts.

The structure described above is that of a typical conifer, *i.e.*, needle leaf tree.

Broad leaf trees are composed not only of trachieds, medullary rays and resin ducts, but also of other elements. Those composing the beech are typical and are shown in Fig. 4. Here:—

c is a trachied.
d is a wood fibre.
a and *b* are wood vessels.
e is a wood parenchyma.
f and *g* are two kinds of medullary ray cells.

Summarising then, a tree is composed of conical layers, one layer being added per year. These layers are built up of trachieds, wood fibres, vessels, etc.; the sizes of elements are not constant throughout, but vary according to season.

A cross section XY (Fig. 5) of the tree contains a series of circles which on account of the periodically varying structure may be seen by the eye as colour differences, and are called annual rings.

There are radial structures perpendicular to the axis of the tree called medullary rays, and running in various directions in the cross section may sometimes be seen bright lines or dots, wood parenchyma.

A radial section shows up the medullary rays, which may be very large and distinct as in oak or tiny and indistinct as in spruce.

We are now in a position to consider how by the study of these anatomical features a given sample of timber may be identified; but we must first consider what degree of magnification we propose to adopt, and method of such magnification.

An ordinary pocket magnifier, consisting of three lens, can be bought for about 5s. or less, and will magnify 10 diameters with all three lenses together. This magnification is sufficient to enable a great deal of identification to be done when skilled. But it is not at all satisfying in so far as one cannot see the trachieds in most conifers, nor details of the medullary rays and other features.

For this reason one is led to obtain either a very powerful Coddington lens magnifying up to 25 diameters, or better, a simple microscope.

The purpose in view is to examine a given piece of timber without going to the labour and expense of cutting and mounting sections in the usual manner adopted by microscope workers.

The microscope which the author is about to describe is very effective for this purpose, and is quite inexpensive; it is illustrated in Fig. 6. It consists of:—

(*a*) A $\frac{2}{3}$ inch objective. It is best to obtain one suitable for a 160 mm. tube microscope, the tube of the author's microscope being short so as to enable it to be carried in the pocket.

(*b*) A Huygen's eyepiece (5 powers magnification).
(*c*) A tube in which (*b*) can slide, but is held by friction, the tube being split at the end to give a spring grip. This tube is covered with lamp black on the inner surface.
(*d*) A circular piece sweated into (*c*) and screwed to take the objective (*a*).
(*e*) An automatic focussing gauge consisting of a brass tube fitting on the nose of the objective (*a*), and cut away at the other end to form three prongs, which stand on the timber and yet admit light.

To prepare a surface the author finds that the only satisfactory way, that does not involve the use of a microtome, is to press a sharp knife into a corner of the wood parallel with the section required, and then the knife having been pressed with a single sliding action as far as it will go, pull away the cut-off piece of timber with the knife. Do not attempt to saw to and fro with the knife; a small clean cut is all that is required.

The spot is then examined by putting two of the prongs of the microscope on the timber and pivoting round them for focussing, the eyepiece having been previously pulled out to a known mark. For examining the side of the grain, such as the radial section, an ordinary planed surface may be used, the microscope standing on three prongs. Better detail, though more difficult to focus, can be found on the surface of a split-up piece of timber where no knife or plane has ever rubbed.

Plenty of light must be flooded on to the surface being examined by a closely placed electric bulb.

The microscope described above magnifies 50 diameters; and as the surface may be prepared in a few seconds it is a very handy instrument to use.

In order to occasionally see spiral lines on the trachieds of certain woods, etc., the author is content to view, using the same eyepiece and objective fixed in a wooden tube 20 inches long. Such a contrivance is very difficult to focus, but it is just possible by laying it on its side on the table, the specimen being clamped vertically. The image is of course very distorted, but it is of considerable value when in doubt on some finer detail. Both this microscope tube and the long tube are blacked on their inner surfaces.

To those who have not previous experience the author recommends such a microscope, as although a great deal can be done with only a pocket lens and an experienced eye, the author finds that most people see but little with very low magnifications, until they realise just what type of thing they are looking for—a matter of training greatly helped by the use of higher magnifications at first so as to make the features very large and distinct.

Afterwards the pocket lens is generally sufficient with our present knowledge of identification, except for the detailed division of conifers on an elaborate scale.

Fig. 7 shows an elementary form of identification table depending only on the recognition at three-power magnification of vessels, resin ducts, heart wood, medullary rays, and annual rings on a cross section.

The abbreviations adopted in Fig. 7 are:—

M.R. = Medullary Ray.
A.R. = Annual Ring.

A tree is said to have heart wood when the wood nearer the centre is coloured other than the yellowish white sapwood, which is found towards the outer part of all trees. Not all trees have heart wood, *i.e.*, coloured heart wood.

Pith flecks which are mentioned in connection with birch are little black defects in the wood caused by insects.

The author proposes to next run rapidly through a few slides identifying the timber whose cross section is shown on the slide by use of this table, so as to illustrate the points described.

The timbers are:—

Fig. 8.—Cedar (Cedrus libani).
,, 9.—Redwood (Sequoia gigantea).
,, 10.—Silver fir (Abies pectinata).
,, 11.—Spruce (Picea excelsa).
,, 12.—Scots pine (Pinus silvestris).
,, 13.—Larch (Larix europea).
,, 14.—Oak (Quercus).
,, 15.—Ash (Fraxinus excelsior).
,, 16.—Elm (Ulmus).
,, 17.—Walnut (Juglans nigra).
,, 18.—Birch (Betula alba).
,, 19.—Sycamore (Acer pseudoplatanus).
,, 20.—Lime (Tilia europea).
,, 21.—Beech (Fagus silvatica).
,, 22.—Hornbeam (Carpinus betulus).

Although the table given above is based upon what would at first appear to be the obvious starting points for any table of identification, there are so many features in timber that the number of ways of starting an identification table is very great. Fig. 23 gives the outline of an identification table for broad leaf timber. The features on which it is based are quite different to those of Fig. 7, and it is better than the scheme of Fig. 7 for an elaborate table.

BROAD LEAF TIMBER.

Vessels visible to three-power magnification on a cross section.

Ring Pored.	Scattered Pored.
Every annual ring begins with a row of large prominent vessels. The remaining vessels are smaller. Further division may be made depending on the presence or absence of bright dots or stripes as exemplified by the treatment of the scattered pored woods.	Size and number of vessels generally decrease from early to late wood of annual rings. When the annual rings are not visible this gradation is hardly noticeable.

All or many of the medullary rays are broader than the vessels, and generally visible to the naked eye.	Medullary rays narrower than the vessels, but are in some woods still visible to the naked eye.	Base wood between medullary rays has no conspicuous dots or stripe markings of any kind.

Bright lines (cord parenchyma) run parallel to one another; sometimes, however, broken up into short dotted rows and generally attached to the vessels.	Small bright dots (bright edged vessels) sometimes forming short oblique rows. Sometimes lines of cord parenchyma present at irregular intervals.

Oblique stripes not present or only to small extent. The bright dots are scattered or are in zones.	Short oblique rows of bright vessels frequently altering in direction and producing a flame-like pattern. There may be dark zones on which no marking appears.

Fig. 23.

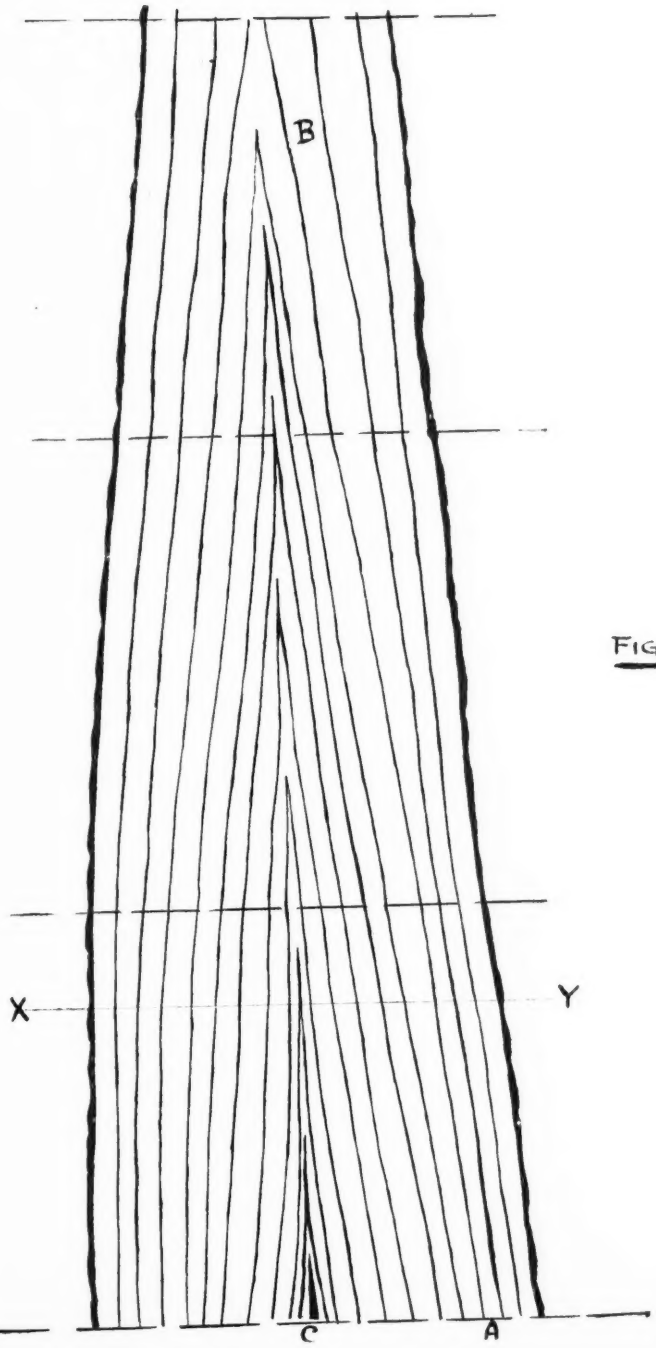


FIG. 5.

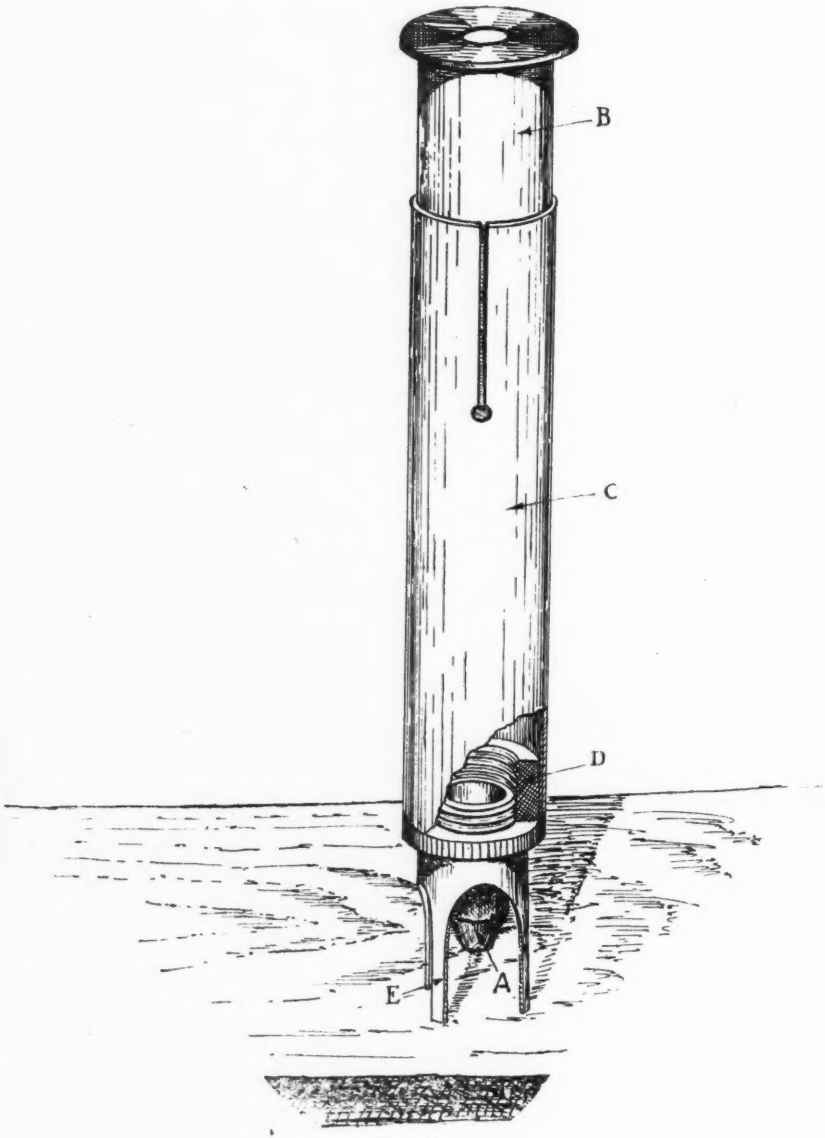


FIG. 6.

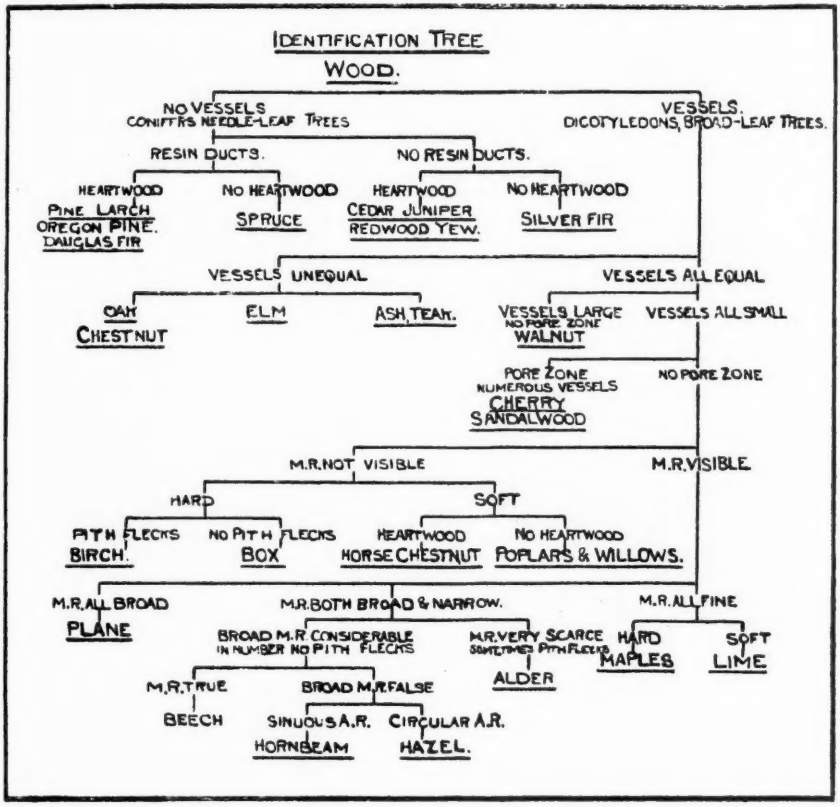

IDENTIFICATION TREE
WOOD.
NO VESSELS
CONIFERS NEEDLE-LEAF TREES
VESSELS.
DICOTYLEDONS, BROAD-LEAF TREES.
RESIN DUCTS.
NO RESIN DUCTS.
HEARTWOOD
PINE LARCH
OREGON PINE.
DOUGLAS FIR
NO HEARTWOOD
SPRUCE
HEARTWOOD
CEDAR JUNIPER
REDWOOD YEW.
NO HEARTWOOD
SILVER FIR
VESSELS UNEQUAL
VESSELS ALL EQUAL
OAK
CHESTNUT
ELM
ASH, TEAK.
VESSELS LARGE
NO PORE ZONE
WALNUT
VESSELS ALL SMALL
PORE ZONE
NUMEROUS VESSELS
CHERRY
SANDALWOOD
NO PORE ZONE
M.R. NOT VISIBLE
M.R. VISIBLE.
HARD
SOFT
PITH FLECKS
BIRCH.
NO PITH FLECKS
BOX
HEARTWOOD
HORSE CHESTNUT
NO HEARTWOOD
POPLARS & WILLOWS.
M.R. ALL BROAD
PLANE
M.R. BOTH BROAD & NARROW.
M.R. ALL FINE
BROAD M.R. CONSIDERABLE
IN NUMBER NO PITH FLECKS
M.R. VERY SCARCE
SOMETIMES PITH FLECKS
ALDER
HARD
MAPLES
SOFT
LIME
M.R. TRUE
BEECH
BROAD M.R. FALSE
SINUOUS A.R.
HORNBEAM
CIRCULAR A.R.
HAZEL.

FIG. 7.

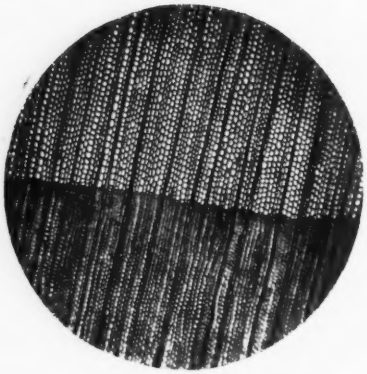


FIG. 8.
Cedar (Cedrus libani).

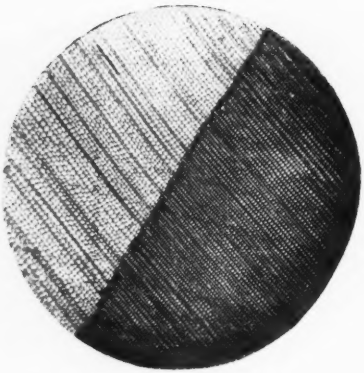


FIG. 9.
Redwood (Sequoia gigantea).

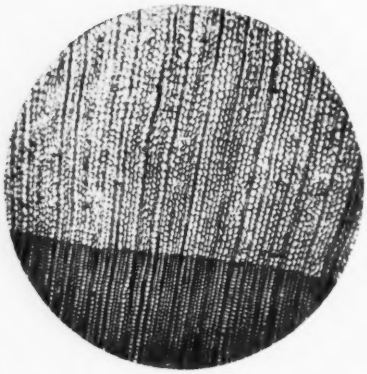


FIG. 10.
Silver fir (Abies pectinata).

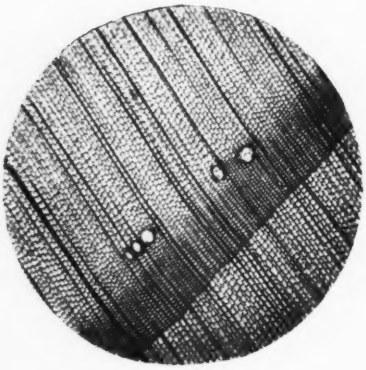


FIG. 11.
Spruce (Picea excelsa).

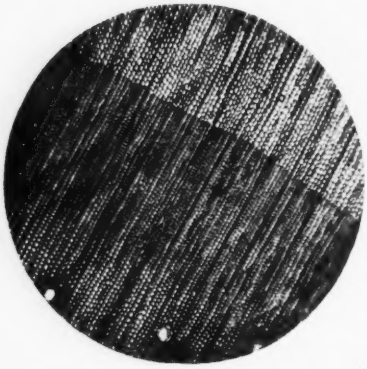


FIG. 12.
Scots pine (Pinus silvestris).

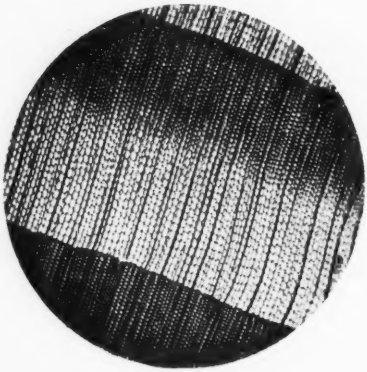


FIG. 13.
Larch (Larix europea).

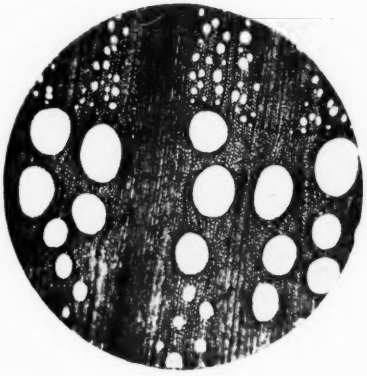


FIG. 14.
Oak (Quercus).

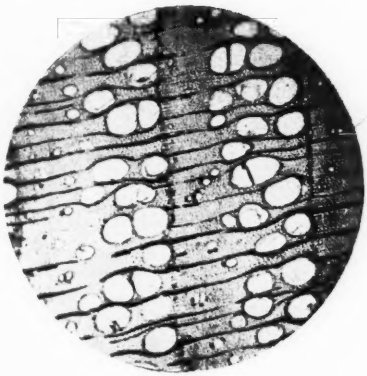


FIG. 15.
Ash (Fraxinus excelsior).

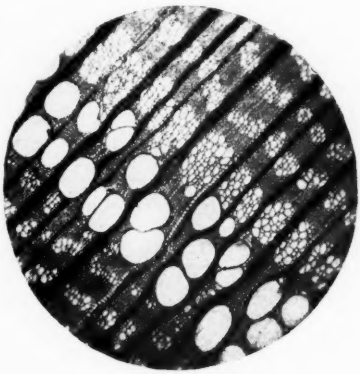


FIG. 16.
Elm (Ulmus).

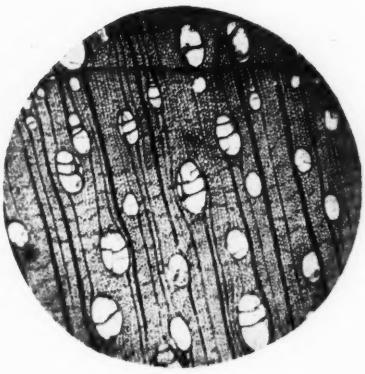


FIG. 17.
Walnut (Juglans nigra).

FIG. 18.
Birch (Betula alba).

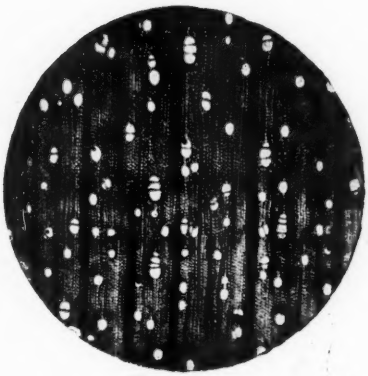


FIG. 19.
Sycamore (Acer pseudoplatanus).

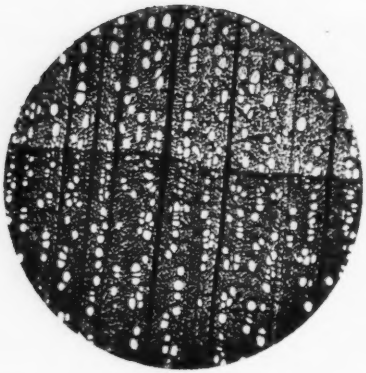


FIG. 20.
Lime (Tilia europa).

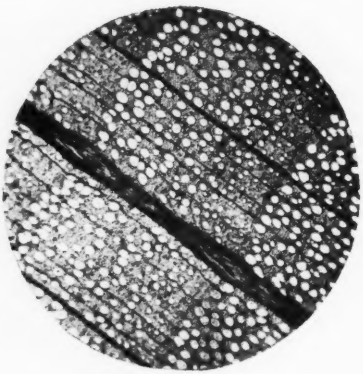


FIG. 21.
Beech (Fagus silvatica).

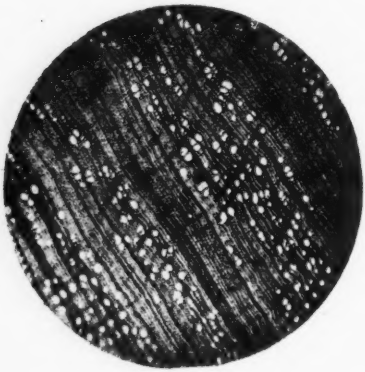


FIG. 22.
Hornbeam (Carpinus betulus).

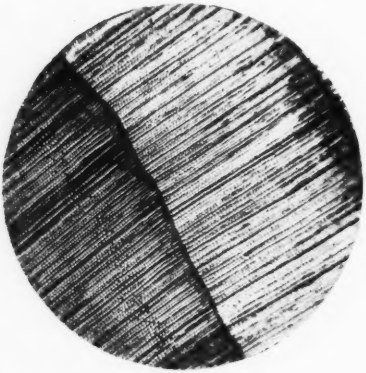


FIG. 24.
Pencil cedar (Juniperus virginiana).

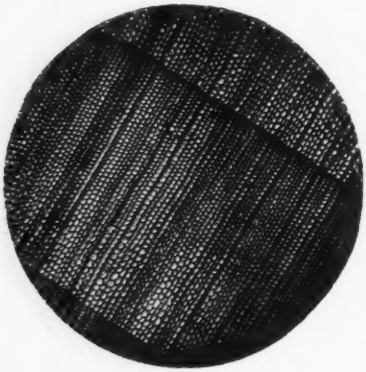


FIG. 26.
Lawson's cypress (Cupressus lawsoniana).

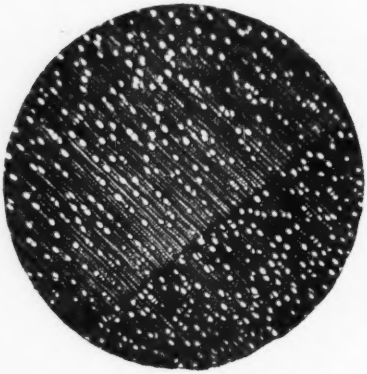


FIG. 27.
Horse chestnut (Æsculus hippocastanum).

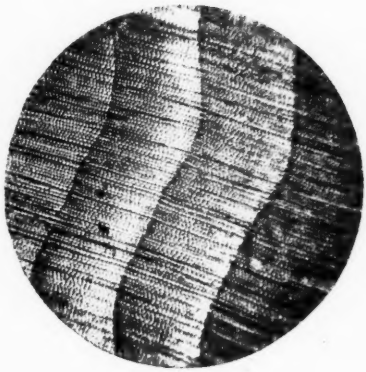


FIG. 28.
Yew (Taxus baccata).

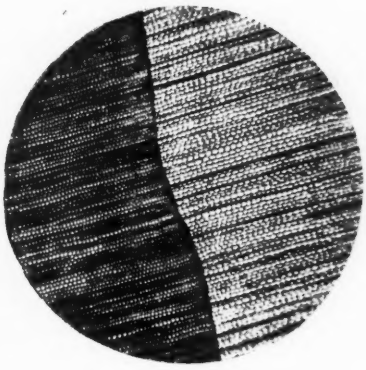


FIG. 29.
Hemlock (Tsuga canadensis).

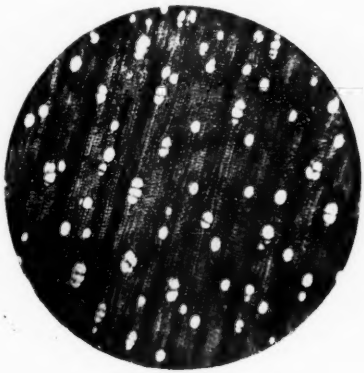


FIG. 30.
Sycamore (Acer pseudopiatanus).

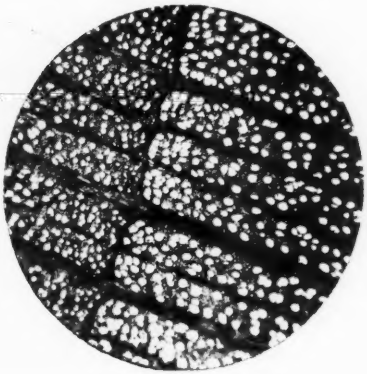


FIG. 31.
Plane (Platanus occidentalis).

FIG. 32.
Ailanthus (Ailanthus glandulosa).

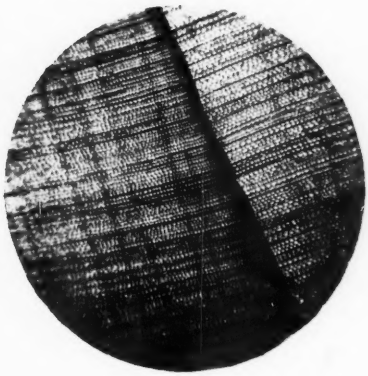


FIG. 33.
Red cedar (Thuya gigantea).

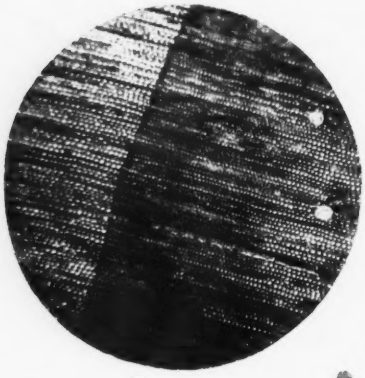


FIG. 34.
Corsican pine (Pinus larico).

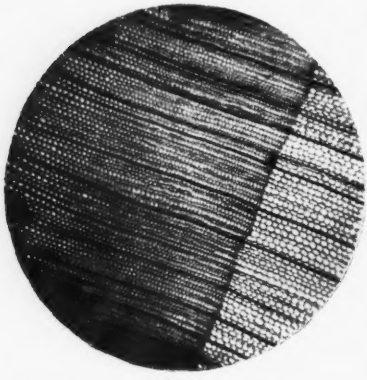


FIG. 35.
Douglas fir (Pseudosuga douglasii).

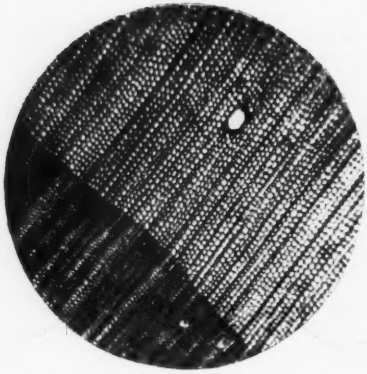


FIG. 36.
Scots pine (Pinus silvestris).

The feature of this table is that it depends for main division on the presence or absence of markings, such as dots or stripes on the base wood between medullary rays and vessels.

Further division is then carried out depending on such details as the following features :—

(1.) Markings on the tangential section. The medullary rays may give a tiny but distinct cross row marking, or knotted marking, or other appearance; *e.g.*, mahoganies may at once be divided into two classes in this way.

(2.) Colour of heart wood. Colour is not a delicate guide, but many woods have a very decided colour, such as black, yellow, red, brown, etc. Ebony is black, or brown, or striped, and is exceptional in this respect.

(3.) The vessels may or may not be choked, *i.e.*, filled with material; such material when present often has a very distinct colour contrasting with that of the wood. The green dots of lignum vitæ (guaiacum officinale) and the white dots of Bombay ebony (diospyros ebenum) are examples.

(4.) If the vessels are grouped together, but are separated from one another only by thin diaphragms, the number of vessels per group may be counted, and will in many woods not exceed a certain number depending on the wood. There may be as many as 50 vessels joined together, *e.g.*, purging buckthorn (rhamnus latharticus).

(5.) The smell of freshly cut shavings is sometimes very distinct. The smell of pencil cedar (juniperus virginiana) is well known.

(6.) The colour of a solution of shavings in water or in alcohol. Water dissolves gums but not resins, whereas alcohol dissolves resins but not gums. By boiling a few shavings first in water and then in alcohol both resins and gums are extracted. Then by adding alcohol to the water solution some of the gums will be precipitated, and similarly by adding water to the alcohol solution some of the resins are precipitated. Other chemical tests are possible, *e.g.*, by the addition of potash to the water solution of the shavings of sappan wood it turns an intense brownish purple.

(7.) Hardness. Mr. H. Stone in his very exceptional book, "Timbers of Commerce," gives a table of hardness having eight distinct grades.

The next thirteen slides, Figs. 24 to 36, are micro cross sections of other common timbers and illustrate the points mentioned above. They are :—

Fig. 24.—Pencil cedar (Juniperus virginiana).
,, 25.—Hawthorn (Cratagus oxyacantha).
,, 26.—Lawson's cypress (Cupressus lawsoniana).
,, 27.—Horse chestnut (Æsculus hippocastanum).
,, 28.—Yew (Taxus baccata).
,, 29.—Hemlock (Tsuga canadensis).
,, 30.—Sycamore (Acer pseudoplatanus).
,, 31.—Plane (Platanus occidentalis).
,, 32.—Ailanthus (Ailanthus glandulosa).
,, 33.—Red cedar (Thuya gigantea).
,, 34.—Corsican pine (Pinus larico).
,, 35.—Douglas fir (Pseudosuga douglasii).
,, 36.—Scots pine (Pinus silvestris).

The author proposes to leave the subject of identification after this brief introduction and to proceed on to a discussion of the mechanical properties of timber.

Assuming, as is roughly true, that all wood substance has about the same density and is composed of the same material, the difference in density of timber is due merely to the presence of holes in it.

If the structures of all timbers were similar and the failure of timber under

load did not depend on any question of the stability of the structure (such as, *e.g.*, is a deciding factor in connection with the failure of steel tubes having walls thin compared with their diameter), but depended only on stress considerations, then it is evident that the strength of timber would be proportional to its density.

As a matter of fact, in spite of considerable variation in the structure of timber, the law that the strength is proportional to the density is roughly true provided that the wetness of the timber be the same for all.

There are many exceptions to this rough rule, but if one limits oneself to one particular species of timber the rule becomes much more precise and is of considerable practical importance.

It is of interest to point out that the word "mahogany," greatly used in the aeroplane world in connection with the manufacture of airscrews, does not refer to a particular species of timber, but is applied to a great number of widely differing timbers, as may be seen by a study of the anatomical detail of them.

Fig. 37 gives a list of a few woods all called mahogany. The tables show the values of the ratio $\frac{\text{strength}}{\text{density}}$ and it is seen that this ratio is far from constant, probably mainly due to the great structural differences which are present.

To specify that an airscrew shall be made of good mahogany is no more precise than to specify that an engine connecting rod shall be made of good steel to be chosen by its colour and sometimes assisted by rough mechanical tests.

TESTS ON MAHOGANIES

NAME	DENSITY	BENDING		COMPRESSION		INDENTN
	LBS PER CU. IN.	ULTIMATE STRESS	STRENGTH WEIGHT	CRUSHING STRESS	STRENGTH WEIGHT	LBS PER SQ IN FOR ·02 INS
SEKONDI	·022	8200	·62	5800	·75	1190
GRAND BASSAM	021	9600	·76	6800	·91	1220
SAPELI	·026	5600	·36	5000	·55	1440
BENIN	020	8500	·71	5500	·78	1290
LAGOS	·022	9500	·72	6900	·89	1370
AXIM	·019	7000	·62	5400	·80	890
KHAYA SENEGALENSIS	·019	9240	·81	—	—	1610
BURSERA	·022	12260	·93	—	—	1920
SOLOMON ISLES	·021	12100	·96	6250	·84	—
TABASCO	·021	9700	·77	6170	·83	2100
HONDURAS	·020	12000	1·0	7080	1·0	2160

FIG. 37.

It would appear that our present definition of mahogany is little better than a wood of mahogany colour.

From about fifty tests on fairly long selected spruce beams obtained from a great many sources the author finds that the ratio

$$\frac{\text{Ultimate stress in lbs. per sq. inch}}{Wt.\text{ in lbs. per cubic inch}} \text{ averages about } 5.9 \times 10^5.$$

Other test results for spruce are given in Fig. 38.

The most complete research on the mechanical properties of European timber which the author has found is that done 80 years ago by Guillaume Wertheim, and is recorded in his "Memoires de Physique Mecanique—les Proprietes Mecanique des Bois." This research would be an excellent model for a similar research to be conducted at present to include timbers other than European.

He chose his trees from 10,000 acres of forest land, grown and felled under the conditions which were exactly known. The forests were situated on three different soils, viz., Vosges sandstone, streaky sandstone, and conchiferous chalk, in each of which were soils of three distinct qualities, viz., dry and arid, fertile, muddy.

The situation of the tree, including the nature of its surroundings, were also noted, and a research was made to find the strength and elasticity of the

SPRUCE

TESTS ON SPECIMENS CUT FROM FOUR BAULKS OF SELECTED TIMBER.
MOISTURE: SOMEWHAT GREATER THAN 10%
AVERAGE DENSITY: ·016 LBS PER CU. IN.; 150 TESTS. FLUCTUATION ± 20%

PURE BENDING TESTS:-

		AVERAGE LBS. PER SQ. IN.	N° OF TESTS	FLUCT^N
BEAM PARALLEL TO GRAIN.	ELASTIC LIMIT STRESS	6200	70	± 25%
	ULTIMATE STRESS	12500	40	± 10%
	YOUNG'S MODULUS 'E'	$1{\cdot}9 \times 10^6$	100	± 20%
BEAM PARALLEL TO RADIUS.	ELASTIC LIMIT STRESS	300	50	± 50%
	ULTIMATE STRESS	1000	50	± 30%
	YOUNG'S MODULUS 'E'	$\cdot 11 \times 10^6$	50	± 10%

TORSION TEST:-

		AVERAGE LBS. PER SQ. IN.	N° OF TESTS	FLUCT^N
TORSION ABOUT AXIS PARALLEL TO GRAIN	TORSION MODULUS 'N'	08×10^6	4	± 10%

THE ABOVE FIGURES HAVE BEEN REDUCED TO AVERAGE DENSITY OF 0·016 LBS PER CU. IN. ON THE ASSUMPTION THAT THE STRESSES AND ELASTIC CONSTANTS ARE PROPORTIONAL TO DENSITY.

FIG. 38.

timber, both along the grain and perpendicular to it, radially and tangentially to the annual rings. The effect of the position of the specimen in the tree with regard to the cardinal points (N., S., E., W.), and its height from the base and radius from the centre of the tree was investigated.

The total number of trees felled for these experiments was ninety-four, and included oak, beech, fir, pine, yoke elm, birch, acacia, elm, ash, sycamore, maple, aspen and poplar, and the experiments lasted many years.

As all the main conclusions which were obtained, when considered in the light of modern knowledge, agree with later experiments, the author proposes to state these conclusions, hoping thereby to satisfy the requirements of war time.

When I speak of mechanical properties in what follows, the elasticity, as well as the strength, in the three principal directions is meant.

The specimens taken from the same annual rings, but from different parts of the tree, with regard to the four cardinal points, did not show any regularity in the variation of mechanical properties. Hence, the mechanical properties are independent of the position with regard to the cardinal points.

Wertheim went quite elaborately into the effect of wetness on the mechanical properties, and reduced all his results to the equivalent corresponding to a standard wetness of 20 per cent. by means of empirical laws based on subsidiary experiment.

He found that generally the density diminished with dryness, the elastic modulus increased, whilst the maximum elongation diminished with dryness, all linearly. The tenacity increased with dryness until by artificial seasoning only about 10 per cent. moisture remained when the timber became brittle and further desiccation led to a diminution of strength. All these experiments on the subject of the effect of wetness had to be done on similar specimens in the same annual rings and situated all the same distance from the base of the tree.

Perhaps the most interesting results of Wertheim are those referring to the effect of distance from the pith or centre of the tree. In the case of fir, pine, elm, ash, maple, sycamore, aspen, and alder, the mechanical properties increase in a steady manner from the centre to the circumference. Hence, for these timbers, wood showing annual rings having only slight curvature is strongest, other things being equal.

In coniferous woods this increase with radius is very great, the modulus of elasticity of the outer rings being often double that of the inner rings near the centre of the tree. Acacia in general follows the same law, but oak and birch are quite different. Here for old trees the mechanical properties improve as far out as about one third of the outside radius, and then diminish to the circumference. With beech the properties improve as one goes out from the centre in a young tree (50 years), but in the case of old trees (100 years) the reverse is true.

Wertheim inferred that for species whose annual rings remain at all ages permeable to fluids, such as the conifers and the majority of white woods, the mechanical properties always increase from the centre to the circumference, no matter what the age of the tree may be; whereas in timbers whose oldest rings go to form heart wood this conclusion is not true for trees of all ages.

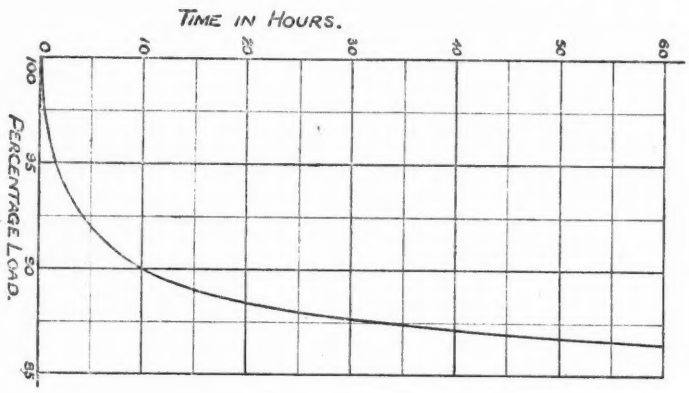
The effect of height from the base of the tree is also of interest. Assuming that one considers always the same annual rings the mechanical properties diminish with the height from the base of the tree. But it must not be deduced from this that if the tree be divided into logs, the average wood in the top log is worse than the average wood in the lowest log.

As seen in Fig. 5 the rings C, which in most species are the worst rings of the lowest log, are not present at all in the upper log, as the annual rings are sections of a series of superimposed cones. So that although the wood at A is better than that at B the average timber in the upper log may be little worse than, or even better than, that in the lowest log in those species whose mechanical properties improve as one chooses specimens further and further from the centre.

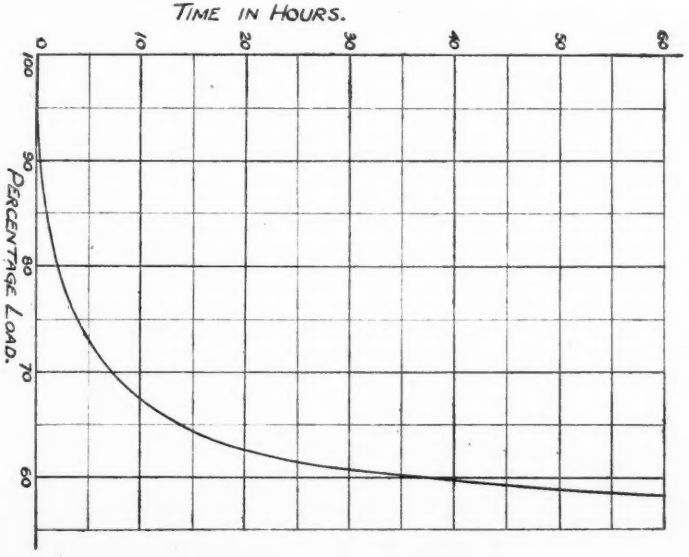
Usually, however, the wood at the foot of the tree is somewhat better than

that higher up the trunk, and is markedly so in those trees in which the mechanical properties get worse as one goes outwards towards the bark.

Wertheim found that the relations between the modulus of elasticity and the tenacity in the direction of the fibres and perpendicular to them do not vary much



CURVE SHOWING THE INFLUENCE OF TIME ON A BEAM SUBJECTED TO SIMPLE BENDING.



CURVE SHOWING THE INFLUENCE OF TIME ON A BEAM SUBJECTED TO BENDING TOGETHER WITH AN END LOAD.

with height in trees of the same species, but a good deal when one compares different species. As average figures, taking for units Young's modulus and the tenacity in the direction of the fibres, the elastic moduli in the radial direction and in a direction tangential to the annual rings are .165 and .09 respectively; and the tenacities in these two directions are .163 and .16 respectively.

With regard to choice of trees it was found that woods from north, north-east and north-west situations and from dry soils always have a high modulus of elasticity; whereas trees from muddy soils have the lowest modulus. This effect is very marked in beech.

The application of most of these results is self-evident, but other applications will appear when they are better known.

Since the interplane struts of aeroplanes are exposed to air resistance they should be of timber more carefully selected than that for the spars which are faired off by the wing and which therefore could be made larger with less loss. For these reasons it might pay in machines of especially high speed for special purposes to use struts of smaller size but of the same strength, the timber being more carefully selected, and showing annual rings of only slight curvature, this timber being dried to a moisture content of 10 per cent., and then the ends painted with several coats, the sides with one coat to preserve the dryness. This is hardly a wartime proposition, as one has such little timber from which to select, but it may be of interest.

A generalisation which the author believes to be true is as follows:—

The deflection or distortion produced by loads on timber is in general composed of an elastic part which is practically proportional to the loads and a permanent part measurable even for relatively small loads, whose magnitude varies not only with the load but also according to the time during which the load acts.

That there is a time effect of considerable importance may be shown by loading beams up to say 80 per cent. of the load which they would stand if it were applied quickly as in ordinary testing (ten minutes), the 80 per cent. load being left on day and night.

It is the author's opinion that a wooden beam can be broken by any load in excess of 50 per cent. of the load which it would stand if the load were applied in ten minutes, the partial load being left on the beam for a sufficient time. Under these conditions there is a slow "creep," *i.e.*, the deflection increases more and more until finally the beam becomes quite unstable and crashes.

Fig. 39 gives the results of some experiments on this subject.

The left hand diagram shows the results of some tests on beams subjected to loads applied at two points between the supports. Thus, 90 per cent. of the load which would break the beam in ten minutes if allowed to remain on the beam would cause it to crash in ten hours.

The right hand diagram shows the results of some tests on beams subjected to a large end load in addition to the lateral load. In this case if the end load and lateral load together produce a stress of only 68 per cent. of that stress which a beam without end load would just stand if it were left on for ten minutes, the beam with combined load would fail in ten hours.

Finally, I should like to record my deep indebtedness to the Superintendent of the Royal Aircraft Factory for his kindness in allowing me to use the lantern slides of timber sections. It was under the able leadership of Major H. Grinsted, O.B.E., that the author first studied the mechanical properties; whilst he was indeed fortunate to have been, some years ago at the Royal College of Science, a student of Professor Groom, now of the Air Board, whose able lectures on the identification of timber formed an excellent foundation for later work.

The author has recently joined Mr. W. G. Tarrant, of Byfleet, an exceedingly successful exponent of timber construction about to prove that aeroplanes even of the largest size can be constructed with advantage almost entirely of timber.

PROCEEDINGS.

EIGHTH MEETING, 53rd SESSION.

The Eighth Meeting of the Fifty-Third Session was held in the Theatre of the Royal Society of Arts, London, on Thursday, April 11th, 1918, Prof. Percy Groom, D.Sc., F.L.S., occupying the chair.

Mr. W. H. BARLING, B.Sc., Associate Fellow, gave his lecture on "Timber."

The CHAIRMAN said they were much indebted to Mr. Barling for the very interesting paper he had given them. He had shown that wood was not a material, but a very unique structure, and that it had mechanical virtues. Especially he mentioned the high quantity represented by the strength divided by the specific gravity, or the weight. But wood, at the same time, had some rather grievous difficulties. He touched incidentally upon the fact of the great difference between the strength when it was twisted along the long axis, along the grain, and transversely, and that exposed us to the very grave practical difficulties encountered when we had to deal with wood with cross grain or wavy grain, when the transverse factor stepped in. But, even apart from that, wood showed itself not to be a material in the variation in the strength and in the modulus of elasticity in very similar diameters in two different species, such as elm and ash, or even in one and the same diameter. Even with the same piece of timber, one could load it with moisture and reduce its dry strength to a third. Comparing two different samples of the same timber, one might be only one third or half as strong as the other under compression or in the modulus of elasticity. So that the same timber might vary 600 per cent. in its strength. That emphasised the opening remarks of Mr. Barling on the necessity for identification. They had not only to identify the different types and species of timber, but to be able to identify wood from the point of view of quality of one and the same class of wood. He thought, from the practical point of view, the latter standpoint was the more interesting, *i.e.*, the point of view of being able to judge of the qualities and particularly the mechanical strength, by the appearance. There was a very pretty example of the effect of structure upon the qualities of the wood and upon its identification that had been discovered recently. He did not think that it was very imprudent to mention it. There was an Indian wood known as padouk. When one tested it in bending it was found to be very extraordinary. It was a very strong wood, and, in bending, its elastic limit was reached at the same time as its extreme breaking stress, so that, from the practical point of view, it was infinitely brittle. With the naked eye, looking at the radial surface, one saw the medullary rays, that Mr. Barling had spoken of, and large cross or transverse markings, and looking at the surface from the tangential and peripheral one also saw the transverse markings, which the practical man called ripple markings. That was due to the fact that padouk was one of the woods which, instead of having its constituents dovetailing, had its fibres meeting together and touching end to end, and the result was that when one examined the structure—though the fact had never been established—one would probably find a certain rupture, and the coincidence of the elastic limit with the breaking strain was due to the peculiar structure. But that structure did not inevitably lead to that result. With regard to mahogany, the mahogany prescribed for propellers was Honduras mahogany, but it was mixed up with Nicaragua mahogany, and (he hoped no members of the Aeronautical Inspection Department were present) it was occasionally mixed up with things that were neither. The ripple markings could be seen in the Honduras mahogany, but they knew that the fracture of that was not a sharp fracture and the elastic limit did not coincide with the breaking stress. The ripple markings were not due to the fact that the ends did not dovetail, but to the fact that the medullary rays, instead of being arranged

in spirals, opened up at the same level. Mr. Barling mentioned a very large generalisation, viz., that there was a proportion between the weight—*i.e.*, the specific gravity—of wood and its modulus of elasticity. He mentioned that it was due to the fact that all wood substance weighed approximately the same. Its specific gravity was about half as great again as that of water—about 1.55. That supplied an explanation of a number of the things Chevalier and Wertheim pointed out, but did not completely understand. He would like to add to Mr. Barling's his praise of the early work of Wertheim, but he would like to add praise of his co-operator, Chavandier. His name had a less teutonic flavour, and he and Chevalier were both Frenchmen. In drawings which he made on the blackboard of the structure of annual rings in Scotch pine, the annual ring in autumn wood—which was called autumn wood because it was *not* produced in autumn—was marked out by red stuff at the end. In the case of spring wood—which *was* produced in spring—the white stuff in the annual ring was white because it was thin walled, there was a lot of air-space and that stuff weighed very light. The red material in the autumn wood was made up of hollow structures with a thicker wall, and therefore it was stronger. Suppose the rate of growth of young Scotch pine—which grew very slowly—was to be reduced to half. If they took a point South and went North or up a mountain, what happened was, even on the same soil, that the so-called autumn wood remained stationary in amount, but the decrease in thickness took place at the expense of that. Therefore, they arrived at the conclusion that in Scotch pine the spring-time wood was sharply marked off, the narrower the annual ring the stronger and proportionately heavier it became. In the Arctic regions that rule ceased, because, owing to the low temperature, the constituents of the wood were not so thick-walled—there was not so much wood substance. Chavandier and Wertheim had their rules about Scotch pine. They increased the rings outwards. In a section of ash one found the peculiar pores Mr. Barling mentioned. The outside part was the strong part. If that ash were made to grow very slowly—if its rate of growth in radial thickness were reduced to half—this (the inner part) kept its former dimensions, and the decrease in thickness was due to the decrease in the strong part of the structure. One got the opposite rule in the ash to what one got in the Scotch pine. One of the most interesting features in Mr. Barling's paper, and one that deserved further investigation, concerned the time factor, and he hoped they would learn very much more about that later on. Another feature that seemed to him to be worthy of more investigation than it had received from the point of view of aeronautics was the power of resistance of wood to shocks. Most people were agreed that the method of recording the resistance of wood to shock by merely registering the resilience—*i.e.*, judging of a dynamic effect by a static test—was eminently unsatisfactory.

Captain BENEST said he had been asked by Major Hope, R.A.F., to submit to the meeting some notes he (Major Hope) had made in regard to woods. Major Hope was an eminent naval architect, and had been accustomed to using wood in light racing yachts for a number of years. He would read the following notes from Major Hope:—

COMPARATIVE STRENGTH-FOR-WEIGHT VALUES OF TIMBER AND OTHER MATERIALS.

I am very glad to note that Mr. Barling has given us some comparative values of various timbers on a strength-weight ratio, as this really gives the constructor the true value of any material when viewed from the point of suitability for light structures.

I would suggest that tables should be prepared giving the values of $\frac{S}{W}$ not only for timbers but for all materials used in aeroplane construction, and that the ratios include the ultimate stresses of (*a*) tension, (*b*) bending,

(*c*) compression (in pounds per square inch divided by the weight in pounds per cubic foot), also the modulus of elasticity.

I have taken the value of W in lbs. per cubic foot rather than per cubic inch, as given by Mr. Barling, because most of the wood workers are more accustomed to this value for weight, and also because it simplifies the formula, by avoiding power and multiples.

As an example, the tensile $\frac{S}{W}$ value of ordinary mild steel of 58,200 lbs. per square inch and 490 lbs. per cubic foot, is 119, while lime tree has a tensile strength of 23,500 lbs. per square inch, and its weight is 47.4 lbs., giving a ratio of 496, or some 315 per cent. stronger for its weight than the steel.

The accompanying table gives a few of these values, which may be of interest, but the chief difficulty at present is scarcity of reliable data.

TABLE OF WEIGHT AND STRENGTH OF MATERIALS.

Name	Lbs. in a Cub. Ft.	Breaking Force.	B.F. W.
ALDER	3.46	9,540	275
ASH	4.50	13,000	299*
BIRCH	4.69	11,671	276
CEDAR (Amer.)	30.8	7,420	240
CHESTNUT	33.4	10,656	318
SPRUCE (Norge)	32.0	12,346	386
SPRUCE (Silver)	27.0	8,000	296
PINE (Yellow)	28.8	8,003	277
LIME	47.4	11,202	237
MAHOGANY (Hond)	35.0	11,475	328
POPLAR	31.9	10,260	324

* Original.

Name.	Lbs. in a Cub. Ft.	Tearing Force.	T.F. W.
ALUMINIUM (Sheet)	166.9	57,000	341
BRONZE, 20 ton (Sheet)	513.4	67,200	131
COPPER (Sheet)	549.1	30,000	55
IRON (Wrt.)	480.0	60,000	125
MILD STEEL, 26 tons	490.0	58,200	119
ALDER	34.6	14,186	410
ASH	45.0	17,000	378
BIRCH	46.9	15,000	320
CEDAR (Amer.)	30.8	10,500	341*
CHESTNUT	33.4	13,300	398
SPRUCE (Norge)	32.0	10,100	315
SPRUCE (Silver)	27.0	10,100	374*
PINE (Yellow)	28.8	10,000	348
LIME	47.4	23,500	496
MAHOGANY (Hond.)	35.0	18,000	514*
POPLAR	31.9	7,200	226
3 PLY BIRCH	45.0	10,000	222*

* Original.

He thought it was rather a drastic thing to say that most mahogany was only mahogany coloured wood. It had been the practice among shipbuilders, and especially yacht builders, to state very particularly in specifications that the wood should go so many pounds per cubic foot and reject all wood that went more.

Mr. GRIFFITHS said the time effect was a much more important matter in transverse moduli—*i.e.*, the shear moduli. He had been trying to get direct longitudinal tension and in experiments he had made he had eliminated the shear. The time effect was then very small. He made some time tests on pure shear torsion and found it was very much greater than in the end stress. In one experiment he took a piece of birch, cut it into two pieces, and made them into round torsion specimens. One he twisted till it broke in about ten minutes and on the other he placed one third of that breaking torque and observed the increase of the stress with time. After about three weeks the twist was about 20 per cent. greater than the breaking twist of the previous specimen, and it was then increasing practically linearly. The specimen was broken under the one third breaking torque and perhaps would have broken under considerably less—possibly a quarter. With padouk he found indications of an elastic limit at about 80 per cent. of breaking load and he took great care to observe any departure from the

linear. Padouk was remarkable. If experiments were confined to pure tension compression there was no time effect observed, and yet there was considerable time effect in the transverse shear and the transverse tension and compression.

Lieutenant-Colonel OGILVIE, R.A.F., said Mr. Barling's and the Chairman's remarks had taught him a lot. He only hoped they would have learnt to do without wood by the time there was none left.

Mr. A. E. PARNACOTT said he had done microscopical and structural work on wood and had found that wood failed where they had tried to join it. It might be helpful if the Author could include in his micro-photo pictures of glued surfaces showing how they were strengthened. Everybody knew the remarkable strength of three-ply wood, and he suggested that that should have more consideration now. By putting up their structures in three-ply wood they would take shorter time and get strengths which were not likely to be got by taking timber more or less in bulk.

Professor G. S. BOULGER: Mr. Barling's paper is of great interest. It is an excellent exposition of the first principles of those portions of a wide subject that he has chosen for explanation. The engineer must know from experience that, as Dr. Groom expresses it, timber is a structure—or rather, I would say, a series of structures—and not a material; and, owing to the wide differences in physical properties between even closely related species, identification of the species is of the utmost and most fundamental importance. It is, however, certainly no easy or simple matter, nor can any simple method of examination make it so. Woods and their physical properties may be compared to a series of chemical compounds, precious stones, metallic ores, or more obscure organic substances. Mere inspection, colour, and density as measured by the hand of an expert may suffice for their identification where they are only required for ornament: as a quantitative chemical analysis may only be required with reference to one constituent in an ore, so a single test may suffice in the case of timber required for the less exacting purposes of carpentry or even building. Even the engineer, however, sometimes fails to recognise the complexity of the strains which he requires his material to resist, and the physical analysis of that material must be as complex as the demands upon it. For this reason I have sometimes doubted whether the statement that, "apart from the holes in it," all wood substance has about the same density, is any more helpful to the timber-valuer than it would be to suggest to the analytical chemist that all the elements may be forms of hydrogen or of some primordial element. It is presumably because wood is a low-priced commodity that mere rule-of-thumb methods have been generally considered sufficient for its examination. I have generally found examination by reflected light quite inadequate, though I have, on account of the difficulty of illumination, employed somewhat lower magnification than that afforded by Mr. Barling's ingeniously simple compound microscope. Thin shavings can be made without a microtome and are much improved for microscopic examination by being dyed. Surely anyone dealing with large quantities of woods of different kinds might expect to have to instal a simple testing laboratory and I should suggest that part of the equipment of any such laboratory should be a projection lantern by which sections taken in all directions can be readily so enlarged that the entire structure of the wood can be studied. Dr. Groom's illustration of the dependence of physical properties upon structure from the case of padouk is extremely interesting. Another example nearer home is that of the sinuous rings of hornbeam—the "yoke elm" of Mr. Barling's translation from Chavandier and Wertheim—which fit it for the complex strains of the cog-wheel and the printer's roller.

I fully agree with Mr. Barling as to the valuelessly vague sense now attaching to the name mahogany, a vagueness which unfortunately vitiates many other names; but a much greater difficulty arises from the fact that when a wood is precisely identified botanically we are very far from knowing what are ironically called its physical constants. It is all very well for Mr. Barling to speak

theoretically of the testing of parts of the same annual ring; but in practice the two ends of a scantling are not made up of the same structural units, and the variations in physical characters between trees of the same species, whether grown under dissimilar or even under identical conditions, and even between different parts of the same tree, are so great that the engineer may fairly say that wood as a material cannot be certainly true to sample, or that tests are little more than tests of individual specimens. No wonder that the aeroplane-builder sighs for some material as strong and light but more reliably uniform. Mr. Barling's practical suggestion of the usually greater strength of wood showing less curvature in the rings amounts to a recommendation of the wood of large trees; and, since (though no engineer) I gather that for many of our present purposes uniformity of texture is even of greater importance than strength, I would suggest that some of the large and cylindrical stems of close-grown timber without side branches, such as the Douglas spruce of Western America and the Cedrelas of the tropics, may be most useful in this respect.

The excellent example of Chavandier and Wertheim in recording the situation of the trees tested by them was followed—no doubt unconsciously—by Professor Johnson, of the United States Forest Department, in 1891-2; Bauschinger, of Munich, in 1883-7 arrived at the same conclusion as to the increase of the mechanical properties from the centre to the circumference; and H. D. Tiemann, in Bulletin 70 of the U.S. Forest Service (1906), fully investigated the effect of moisture upon strength. Dr. Julius' work on West Australian timbers (1906) and Mr. R. S. Pearson's on those of India (1912) admirably supplement those of Chavandier and Wertheim upon European woods and those of Captain Fowke and others upon those of our colonies; but the very thorough tests carried out by American authorities have not only been restricted to American woods, but have not been brought into comparison with the results of workers elsewhere. I know of no better exposition of the mechanical properties of wood than that in the work bearing that title by Professor Record, of Yale; but in these days, when a serious demand is ransacking the world's commerce, a more comprehensive comparison of the timbers of the world is required. For this purpose, unfortunately, the varying testing systems of different previous investigators render their results almost useless.

The SECRETARY inquired whether any use could be made of apple and pear wood in airscrew manufacture. Both these woods were hard and took a high polish. There were in the West of England a great quantity of these trees which had long ago ceased to be productive as a source of fruit crop. The wood was now mainly used as fuel, which did not appear to be the most economical way of using a high grade timber.

Professor W. SOMERVILLE: I have read with much interest Mr. Barling's suggestive paper, and the useful discussion that followed. He raises many points of importance in regard to the quality of timber, but it was clearly impossible, in the time at his disposal, that every aspect of the case could be reviewed.

There is one matter about which I desire to offer a few observations, and that is, the intimate relationship that may exist between silvicultural treatment and the quality of the resulting timber. What one wants to secure in timber is reasonable freedom from knots, equality of growth, and the avoidance of irregularity in the breadth of the rings. Narrow-ringed coniferous timber is of superior quality to that with broad rings, largely because, as Mr. Barling points out, curtailment of annual growth is associated with reduction in the amount of poor porous spring wood. Silvicultural methods should therefore be directed towards securing a high degree of crowding in coniferous woods at an early stage, so that the excessive growth of youth shall be prevented or rapidly curtailed. The best way of all to secure this is by forming new woods under the shade of the older

generation of trees, the latter being gradually removed as the young trees grow up and begin to crowd themselves. Later on, relief must be given by judicious thinning, which must be moderate in amount at any one time, or otherwise one would get an abrupt change from narrow to wide rings, and such sharp changes constitute lines of weakness in the timber. Generally speaking, if the cross section of a conifer grown in England is examined it will be found that the rings are excessively wide near the centre, and gradually diminish in breadth for about 20 years, when a sharp increase occurs, followed by a further reduction in breadth, until finally, after certain minor oscillations, the rings near the outside may be extremely narrow. Now it ought to be quite possible, in the absence of exceptional circumstances, to secure practical uniformity throughout the stem. And similarly as regards knots. One can never avoid them altogether, but if trees are grown so close together that the lower branches die and drop off while still small, the proportion of knots will be almost at a minimum. Still greater freedom from knots will be secured by pruning off the dead branches close to the stem, and although, for most purposes, great uniformity of texture and freedom from knots is not required, it may well be the case that for certain work, *e.g.*, aeroplanes, it would pay to give detailed attention to selected individual trees.

Hard woods, such as the ash, stand in a different category from conifers, but in their case also individual attention to selected trees from youth onwards would secure exceptionally high quality in the timber, and the outlay might very well be justified by the results.

Mr. HERBERT STONE: In response to your kind invitation to contribute to the discussion commenced by Mr. Barling, I may say at once that, though taking a most lively interest in all matters touched upon, I prefer to leave the question of physics to the very competent persons who have already taken part in the debate. I will, however, make one remark that cannot be repeated too often, that is, *that wood does not follow the law of Galileo* inasmuch as the resistance to transverse strain *does not vary inversely as the length* (it diminishes very much more rapidly), and all formulæ assuming the contrary are vicious in principle and dangerous in practice. This fact was quite well known two hundred years ago, but by a curious process of leakage, due to our habit of ignoring any book not right up to date, has been lost sight of. Even Chavandier and Wertheim fell into the same error, and all the modern authors without, I believe, a single exception, have followed suit. B. E. Fernow, of the U.S.A. Forestry Division, who has probably seen further into these problems than any other, makes the remark that tests made upon large beams (12 feet by 6 to 10 inches side), give results *less than half* those expected from tests made on small pieces (24 by 2 by 2 inches). He does not, however, see that the discrepancy is due to the factor of length.

Apart from this, I recommend all who are interested in Timber Physics to read up the bulletins and circulars of the U.S.A. The Yankees are ahead of us in this direction.

Turning to the question of the identification of woods, where I feel more at home, as it has been my favourite study for 35 years.

There are two sides to be considered. Firstly, the recognition of a wood previously seen, and secondly, the determination of an unknown wood seen for the first time. The first depends upon observation and memory coupled with access to specimens in sufficient variety, and is a trade learnt solely by practice such as is tea-tasting, upon which large sums of money depend.

To identify an unknown wood, on the contrary, we must work by rule and must have some means of classifying or of breaking up the mass of species into groups which bring the research within reasonable limits.

External appearances may aid us, but they frequently deceive us, as in the case of the many-headed hydra called mahogany, hence we have recourse to the structure as pointed out by Mr. Barling. In the vast number of cases similar structure runs through any series of woods that are related to one another. All

walnuts and hickories have precisely the same structure, being of the same family; all elms show the same beautiful lace-like tracery; all oaks the same bold silver grain and radial streams of pores. This fact enables us to restrict our search to a given family or group.

During the past seven years I have devoted my leisure to the construction of a key to the species which will enable the student to run down a wood step by step after the manner sketched out by Mr. Barling, but the conclusion I have arrived at is that such a key must be based upon the structure *as a whole*, that is to say, no tissue, be it rays, pores, or parenchyma (soft tissue), can be chosen as having a greater systematic value than another. It is their ensemble; the manner of their grouping, or what in France is called the *plan ligneux*, must be considered as a whole. Hence, I have compiled a list of alternatives comprising every possible arrangement of each tissue in relation to the others, based upon the study of some 7,000 species. Theoretically, the possible alternatives are infinite, but actually such as I have met with fall into about 70 groups. These arrangements naturally need much description, but by numbering such stereotyped descriptions and by using the initial letters of the tissues together with the numbers, we can crystallise a long paragraph into a single line, otherwise into a formula, which has the advantage not only of brevity but of ready comparison.

Let V = Vessels or Pores.
R = Rays.
Sa = Soft tissue of first category.
Sb = Soft tissue of second category.
— S = Soft tissue absent.

Then V will be a symbol or grammalogue meaning all woods having true vessels which includes all broad-leaved trees, palms and bamboos.

RV = the wood of broad-leaved trees; the palms, etc., being excluded by the presence of rays.
R — V = the wood of conifers which do not possess true vessels.
RVSa = all those exotic woods having few pores (and also some English woods, as the ash and elm), because the vessels are surrounded by soft tissue.
RVSaSb = those woods of most complex structure such as the oaks, which have not only soft tissue surrounding the vessels but another kind disposed in concentric circles.

So much for the main divisions. The subordinate grouping is indicated by numbers following each letter; for instance, VSa123 Sb32 R23 is a condensed description of the structure of the oak, which would otherwise occupy the half of this page.

We first examine our specimen and decide upon its formula, and then by means of a list of woods classed according to formulæ we find a group from which we must choose the one corresponding to our needs. These groups are considered from a different point of view as we now call to our aid the colour, its change upon exposure to the air, colour distribution (stripes, patches, or mixtures of minute elements, as in a three-colour print); the solution it yields with water or alcohol; the surface, whether lustrous or dull, sticky or clean, resistant to friction or smooth; the smell when dry, when wetted and when being worked, and also when burning; the taste, weight, hardness, inflammability, and fracture. It is by means of the comparison of such details, *point by point*, that we are enabled at last to satisfy ourselves about the identity of a wood. Such precision will never altogether displace the faculty of recognising a wood on sight by rule of thumb or scowl of brow. For this reason I suggest that the Aëronautical Society should make a collection of all woods used for aircraft. These should be certified as to the commercial name by trustworthy persons and confirmed as to the scientific name by a technologist, and above all the specimens should be

dressed in a manner permitting the study of their structure, more particularly across grain.

This may suffice until we have something more satisfactory than the fragmentary and empirical keys so far published. Unfortunately such works are of limited sale and publishers fight shy of them, and on the other hand the generous assistance afforded by our learned societies to authors of books on pure science fails almost completely when such science dares to be useful.

I note the suggestion of Lieutenant-Colonel Hope, R.A.F., conveyed by Captain Benest, that tables might be drawn up on a "*strength-for-weight*" principle, of which I did not at first grasp the significance. That this principle may apply to most of the woods used in yacht building is a matter of coincidence and it would be exceedingly dangerous to apply it generally. I need only cite the larch and the pitch pine, whose heavy qualities surcharged with resin, may be of inferior strength to much lighter wood.

Each species must be studied separately because the lines of weakness are different in each and this means a very big task. I therefore make the suggestion that for all aircraft work each wood shall be tested *in the size and length actually used* and the elastic limit found for *the best quality;* then each piece to be bent to that limit before being used in construction. This could be done very simply and quickly by means of a cramp when once the curvature is known. Wood which is bent to a curvature less than that of its elastic limit always returns to its original form, *i.e.*, no change has taken place in the structure so that the process may be repeated without limit. For instance, the bows made of laburnum, used up till quite recently in some parts of France, kept their original elasticity for 50 years, so no harm will be done in testing pieces before use. It has always seemed curious to me that whereas the most rigorous tests are prescribed for metals no one thinks of doing so for timber which is far more "tricky."

Mr. E. J. H. Lynam: I have read with great pleasure Mr. W. H. Barling's excellent paper dealing with the identification of timber. It is a subject of vital importance now, when supplies of the well-known and proved timbers are decreasing rapidly and a search has to be made for various substitutes, some of which are relatively unknown.

One noticeable instance of this is the substitution of mahogany for walnut (Juglans nigra) in airscrew construction. The name mahogany is, of course, by no means unknown, but the same remark cannot be made about the properties of the large number of widely different timbers sold under that name. Certain species of mahogany are undoubtedly quite good for this purpose, but on the other hand, a great number are not, and the question arises how to sort out the good from an enormous number of varieties without some simple means of identification.

To obtain samples of these various species, the botanical names of which are known, and to subject them to mechanical tests is not of much use unless it is made easily possible to identify the timber when planked.

It is here in connection with mahogany that an immense amount of work on identification remains to be done; it is a matter of extreme importance at this time and one upon which the services of the most eminent botanists are urgently required.

From mechanical tests upon named specimens the engineer has already settled upon the varieties which are suitable for his purpose, but the work of the botanist is lacking, with the result that he can seldom identify the satisfactory timbers. He has to be guided entirely by the name under which it is purchased, a name often misleading, and not infrequently in error.

For example, timber sold as "African walnut" is not walnut at all, it being

simply a trade name under which a number of timbers of widely varying properties are sold. The chief timbers usually sold under this name are:—

Apopo Enwiwa (Trichilia).
Owowe (Albizzia).
Odonomokyuku (Boswellia Klainei).

The first comes from Benin (sometimes called Benin walnut) and is possibly the best of the three; the last, however, is distinctly inferior, so that unless it is possible to identify these three timbers easily, the mechanical properties of the wood bought as "African walnut" may vary very widely.

Another important example is the "cottonwoods." Quantities of timber reach this country under the heading of cottonwood or American whitewood. Actually this includes almost all species of poplar (Populus), the mechanical properties of which vary considerably.

Many other examples could be quoted but need not be discussed here, the object of mentioning these two being to emphasise the very great importance of the identification of timber.

It would be of great assistance to all dealing with timber, and especially the aeronautical engineer, if the use of such misleading trade names as those mentioned could be discontinued; each timber could then be sold under its native name, or, if I may suggest the ideal, its correct botanical name. This would remove the necessity for a large amount of identification which, as can be seen, is at present essential.

Coming now to the actual work of identification, I am delighted to see that Mr. Barling uses the tangential and radial longitudinal sections as well as the transverse section; the two former do certainly enable a great deal to be done, although in many methods of identification they are not given the attention they deserve. It is admitted that the differences between various timbers when viewed in longitudinal section are perhaps not so striking to the eye at first sight, but when carefully studied they provide a valuable guide.

The most interesting difference in these sections is possibly the arrangement of the medullary rays on tangential longitudinal sections of mahogany, spoken of by Mr. Barling. Certain mahoganies when viewed on this section exhibit a regular arrangement of the medullary rays in cross rows as in Fig. 1, whereas other varieties show a perfectly irregular arrangement as in Fig. 2.

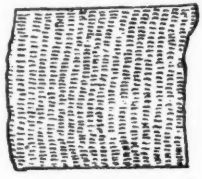


FIG. I.

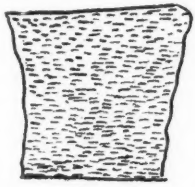


Fig. II.

This coupled with the presence or absence of lines of cord parenchyma in transverse section, gives a valuable means of identifying between American and African mahoganies.

The arrangement in cross rows of the fine medullary rays in padouk when viewed in this section is very conspicuous. Their appearance in acacia (Robinia pseudocacio) is also similar.

There is one point in Mr. Barling's paper upon which I would like to give you a word of warning, and that is the periodic alternations of colour seen in a transverse section, usually known as annual rings. Many exotic and also one European timber (olive) exhibit on a transverse section periodic colour differences

which are not due to annual rings. They are generally termed " false rings " and can nearly always be distinguished from annual rings by a simple test. Such rings, if carefully observed, will frequently be found to run into one another, which is impossible, of course, in the case of annual rings, but unless this is carefully looked for an error can be easily made.

The following are a few well known species of exotic timbers which show false rings:—

Indian oaks (Quercus lamellosa),
Ebonies (Diospyros),
Rosewoods (Dalbergia, Pterocarpus, etc.),
Lignum vitæ (Guaiacum),

and the one European wood

Olive (Oleo europoea).

Generally in timbers exhibiting false rings, the annual rings are indistinguishable.

False rings offer one means of identifying a number of exotic timbers.

I notice that Mr. Barling has omitted to mention one physical test, often of use in identification, and that is the observation of how a splinter of the wood in question burns and the nature of the residue after burning. I believe such a test is practically the only means of identifying jarrah (Eucalyptus marginata) from karri (Eucalyptus diversicolor) when cut. A splinter from jarrah burns to a firm black ash, whereas karri leaves a woolly white ash; further, when the burning splinter of karri is blown out it tends to glow for some little time, whereas with jarrah it is extinguished immediately.

In Mr. Herbert Stone's excellent book, " The Timbers of Commerce and their Identification," mentioned by Mr. Barling in his paper, the behaviour of many woods under this test has been given. The book is particularly valuable in this respect.

Coming now to the latter part of the paper—that dealing with strengths—the question of moisture content is of profound importance, although often entirely disregarded in timber tests. Comparative figures for the strengths of various woods, to be scientifically accurate, should be determined for, or reduced to, the same moisture content.

The difficulty of determining the strength and elastic constants of all woods for the same moisture content is, of course, immediately realised so that in order that this shall not be necessary, we require to know the manner in which the strength and elastic constants vary with the moisture content for all timbers.

Failing this knowledge, the best that can be done is to determine the wetness of the timber for which the strengths, etc., are given. This will avoid comparisons being made between the strengths and elastic constants of various timbers determined at different moisture content. Such comparisons are frequently made, even to-day, and the results may be quite misleading and dangerous to employ.

The curves on Plates I. and II. show the manner in which the various strengths, etc., of wood vary with moisture content. Plate No. I. gives curves taken from Bulletin No. 8 of the U.S.A. Department of Agriculture, and apply to the long-leaf pine or pitch pine (Pinus palustris) of U.S.A.

Plate No. II. shows similar curves for jarrah and have been taken from " The Physical Characteristics of the Hardwoods of Western Australia," by G. A. Julius, B.Sc., M.A., published by the Government of Western Australia.

It will be noticed that the curves are of very similar shape even for woods so widely different as these two, and it is not unlikely that corresponding curves for all other woods are much the same.

Before concluding I would like to give a very rough and incomplete identification table for mahogany on the lines suggested in Mr. Barling's paper. It is inserted chiefly to show the very scanty nature of our knowledge of this subject. Perhaps it may so dissatisfy others as to induce them to investigate further.

In the following table T.S. indicates "transverse sections" and L.S. "longitudinal sections."

MAHOGANY.

(A) *Ring-pored.*

Each annual ring begins with a region of larger vessels producing prominent furrows in longitudinal sections. The remaining vessels are smaller and distributed.

(1) CEDRELA ODORATA (CIGAR-BOX CEDAR).

The ring-pored nature of this wood is sometimes difficult to see, especially in small pieces.
Colour—Cinnamon brown.
T.S.—Medullary rays only just recognisable. Bright lines of cord parenchyma.
L.S.—Closely needle rent and lustrous. Larger furrows filled with dark red to black substance.
Soft, light, easily split, pleasant aroma.

(B) *Scattered-pored.*

(1) Vessels small and seldom choked.

(*a*) Light or dark cinnamon—brown to reddish—brown darkening on exposure.
T.S.—Prominent medullary rays often slightly twisted. Fine bright lines of cord parenchyma at almost equal intervals.
L.S.—Thickly needle rent, the furrows being often grained, lustrous, and containing a red to black filling.
Medullary rays in cross rows on tangential surface. Difficult to split.

MAHOGANY (SWIETENIA MAHAGANI).

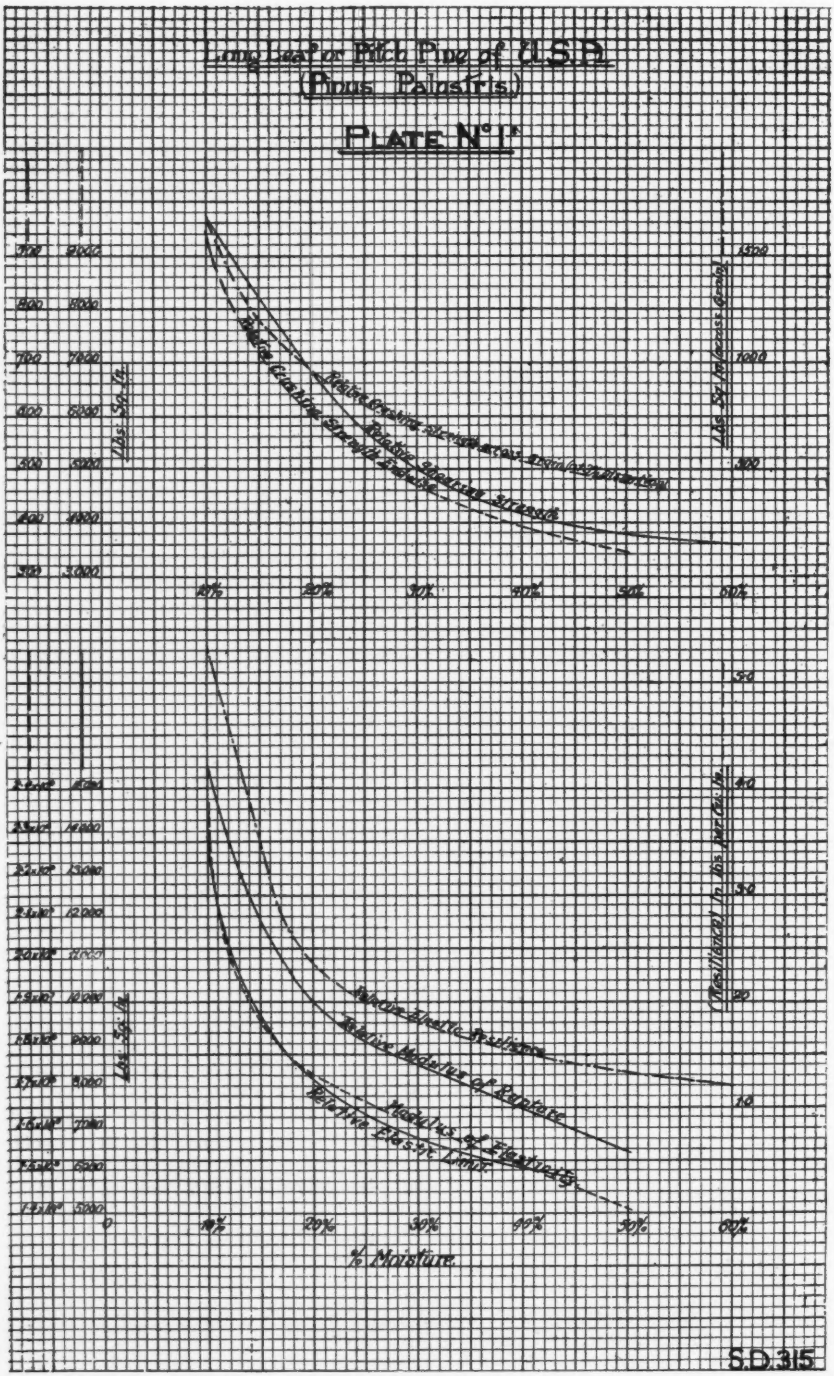
This includes Swietenia from Cuba, Corrinto and Domingo. Sp. gr. varies with these timbers from .56 to .87, also the hardness.
The heaviest is probably Cuban mahogany.
In Domingo timber the vessels very often contain a white substance.

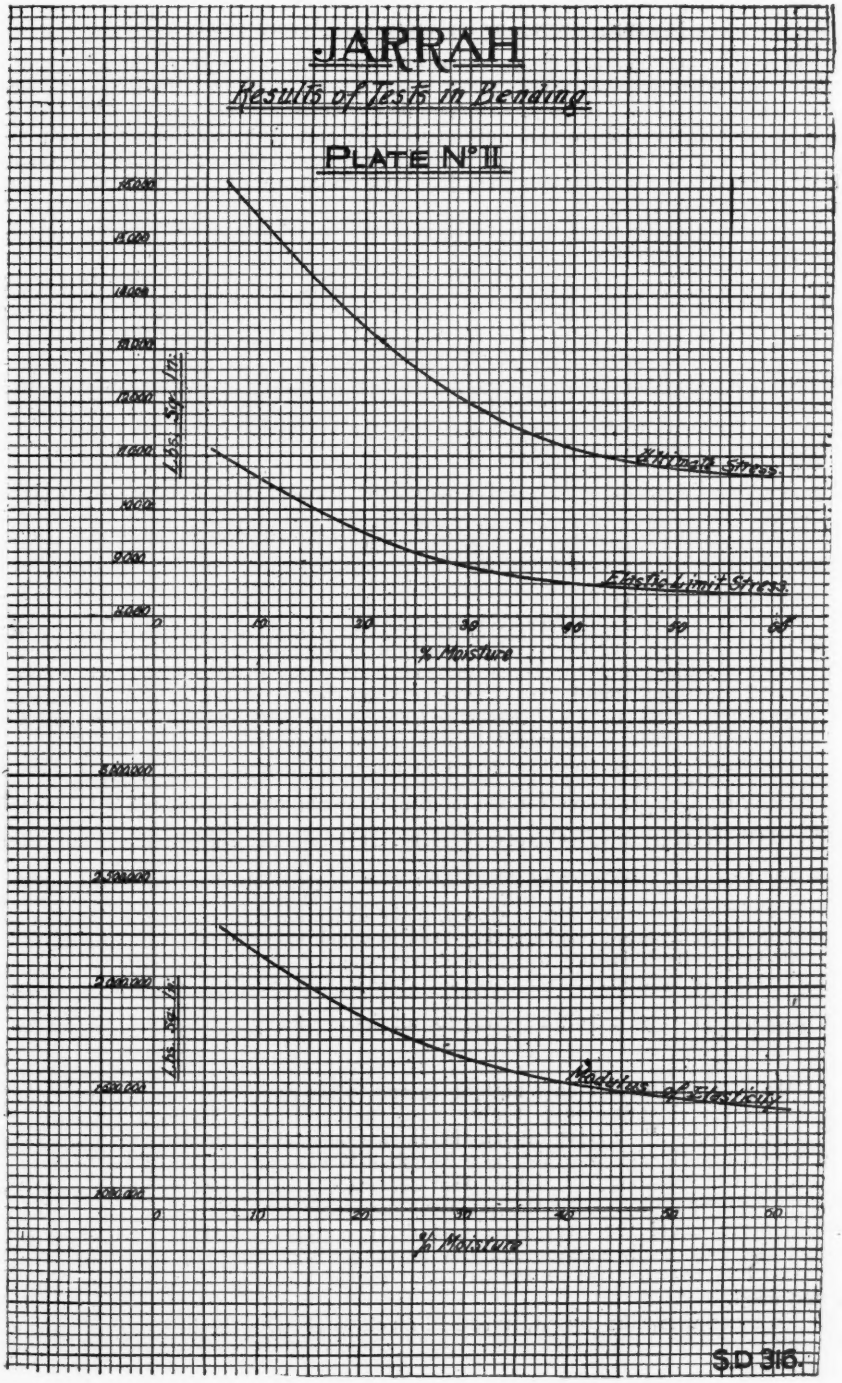
(*b*) Light reddish sometimes exhibiting a grey tinge.
T.S.—Annual rings visible without, in general, bright lines of cord parenchyma.
L.S.—Medullary rays not in cross rows.

AFRICAN MAHOGANY.

Under this head are a great number of timbers, most of which are named after the places from which they come. The most important, probably, are the following:—Lagos, Sekondi, Benin, Grand Bassam, Axim, Sapeli, Khaya, Okume and Gubun.
Lagos, Sekondi, Okume and Gubun are brighter reddish, or reddish grey, with an indication of longitudinal striping due to irregular vessel and fibre growth.
Vessels in Lagos and Sekondi generally filled with dark red to black substance.
Vessels in Gubun and Okume usually not filled.

(C) Light ochre to golden yellow.
T.S.—Prominent annual rings.
L.S.—Lustrous with wavy, irregular and usually unfilled furrows.
Light, soft, and easily split.


Long Leaf or Pitch Pine of U.S.A.
(Pinus Palustris)
PLATE N° I.
Lbs. Sq. In.
Lbs. Sq. Inch
Kilogrammes per Sq. Centimetre
Modulus of Rupture
Modulus of Elasticity
Elastic Limit
% Moisture
S.D.315


JARRAH
Results of Tests in Bending.
PLATE N°II
Ultimate Stress.
Elastic Limit Stress.
% Moisture
Modulus of Elasticity
% Moisture
SD 316.

MADEIRA MAHOGANY OR VENATICO (PERSEA INDICA).

There is still another group of woods for which, I believe, no means of identifying exists at present, viz., eucalyptus. This group includes a large number of exceptionally strong timbers. Unfortunately, however, they are all very heavy and in most cases exceptionally difficult to work and very liable to warp, and so unsuitable for aeronautical work. Perhaps this is a sufficient excuse for their identification to be left unattempted, but such an excuse cannot be made in the case of mahogany.

In conclusion, I would like to thank Mr. W. H. Barling for his extremely interesting and valuable paper.

Mr. H. A. WEBB: I have read with great interest and pleasure Mr. Barling's paper on timber. I endorse his appreciation of Wertheim, who recorded phenomena with care and accuracy even when he could not explain them. Mr. Barling very properly emphasises, as one of the important features of the æolotropy of wood, its weakness in cross bending; this is probably the explanation of the weakness of wood when the grain is not straight. The figures he gives are averages for many timbers; low as they are, the values for spruce and other soft woods are, as Wertheim showed, much lower.

Another important constant for aeroplane timbers is the ratio $\frac{E}{N}$, where N is the modulus of rigidity and E is Young's modulus of elasticity. For isotropic materials, $\frac{E}{N} = 2.5$, but for timber $\frac{E}{N}$ may exceed 20 ("Perry's Applied Mechanics," Appendix I.).

The reason for its importance is as follows:—Wertheim was puzzled to find that bending tests, done by hanging a weight in the middle of a beam, gave low values of E; the stiffer the beam the lower the value. He even tested whole trunks of trees and found that they gave values of E which were often barely half what dynamical, or direct tensile or compressive tests had led him to expect. The explanation, which Wertheim missed, is as follows:—

The deflection due to shear bears to the deflection due to bending a ratio depending on $\frac{E}{N} \cdot \frac{d^2}{l^2}$, where l is the length and d the depth of the beam (Morley, "Strength of Materials," Chapter VIII.). This is usually negligible in metals, but not in timber, because of the high value of $\frac{E}{N}$; and the stiffer the beam the more important it becomes. Hence, if the deflection due to shear is neglected, the value of E, deduced from bending tests in which shear is present, will be low.

Consequently it is safe to use a higher value of E for the design of struts, where there is little shear, than for spars or longerons. The margin of safety depends on $\frac{E}{N}$, which should be found for all timbers likely to be used in aeroplane construction.

Mr. J. S. GAMBLE: I have nothing to add to the remarks made by me on the subject of the identification of timber given in the introduction to my "Manual of Indian Timber." I have quoted therein the scheme of classification proposed by Professors Hartig, Matthieu and Marshall-Ward and Sir D. Brandt, and I have given my reasons for thinking that elaborate general keys would be of very small practical utility. To the practical man engaged in the trade in timber nothing can equal the experience gained by constant handling. In cases of doubt the only really certain test lies in comparison with the type specimens preserved in museums or collections and known to be accurately named and determined.

To those who, like myself, have had much to do with the handling of woods

and have had to devote much time to their identification, the first and most important thing to remember is that in most botanical families there are special characters which should be learnt, and no key though ever so laboriously constructed can ever obviate the need for knowing family characteristics. When once the family has been determined, the rest is easier, and comparison with types is facilitated. The most valuable type collection is probably that made by Professor Nordlinger of thin cross sections. There are some mistakes in it no doubt, but on the whole it is reliable.

Then, for American woods, there are the beautiful sections published by Professor Hough; and there are probably others of more recent preparation which I do not know.

The collections of accurately named wood blocks at Kew, Oxford, and elsewhere are, of course, well known.

In some cases microscopic examination is essential, as Professor Somerville has shown with the conifers, but for general practical recognition microscopic characters visible under a lens are often quite sufficient, as for example can be easily seen in such genera as those of the oaks, elms and ashes.

I regret that my contribution to the discussion can only be so slender.

The AUTHOR, in reply to the discussion, said: To judge the quality of timber by its appearance is certainly a difficult matter, but is of great practical importance.

The Chairman has shown that the same generalisation with regard to the effect on strength of the width of the annual rings does not apply to both large pored timber and conifers. I have tried to emphasise in addition another important indication, viz., the amount of curvature of the annual rings. Timber with annual rings of small rather than of large curvature is preferable in most woods. Of course, cross and wavy grained timber is to be avoided. These points, taken in conjunction with the valuable remarks of the Chairman, were of importance in selecting timber.

With regard to padouk, it was of great interest to learn that the Chairman had found out the reason for the brittleness of this wood, viz., the tiered arrangement of its trachieds. Yet it was extraordinary that this timber had been used to a considerable extent in India for gun carriages and stocks. It was odd that they should use a wood which admittedly had no strength beyond its elastic limit for cases where resistance to great shock was required. It might be that they used it with a great factor of safety. It was used because padouk did not twist so much as other woods and it was exceedingly stiff, which was of great advantage, its modulus of elasticity being high.

The resistance of timber to shock is a difficult characteristic to measure, and I am sure that we should all welcome any research done to determine this important feature of timber. Compared with metal, timber had the property of absorbing vibration, another characteristic upon which some research might be done in connection with aeroplane engine mountings.

I am glad to hear from Captain Benest that the shipbuilder, at any rate, takes great care in choosing his mahogany. In aeronautical work when specimens were cut from airscrews made by a great number of firms it was found, unfortunately, that it was not always selected with any better definition than the one given by the author, viz., "a wood of mahogany colour," thus justifying this drastic comment.

A great deal of the timber called mahogany came from a strip of country some thousand miles long, wooded with great density, along the west coast of Africa, and I believe that many species quite unknown before the war had come into the market and were being used with such rapidity that they would be extinct before there had been time to identify them. But they were all called mahogany.

I think Mr. Griffiths' valuable work on time effect (which he appears to be continuing) should lead to results of great practical importance. I think Mr. Griffiths was the first man to call attention to the fact that the time effect in shear

was much greater than the time effect for wood in tension or compression or bending. The only time effect on which I have worked was that occupied in bending spars by lateral load, both with and without simultaneous end loads. These conditions corresponded with those which occurred in aeroplane spars. It is interesting to note that the time effect with padouk in tension is zero; no doubt they would some day learn the reason why.

With regard to ply wood, I have always found this to be rather heavy when used in aeroplane structures. No doubt ply wood is very strong, but I doubt whether its strength for weight ratio is improved owing to the weight of the glue. The glueing process certainly increased the strength as the glue impregnated almost the whole of the wood in ordinary thin three-ply.

I am sorry that Colonel Ogilvie has, owing to his modesty, not given us the benefit of his great experience on timber.

I am surprised that Professor Boulger should have found microscopic examination of timber sections by reflected light inadequate. When using the microscope described in the paper it is necessary to place an electric light bulb so as to practically touch the specimen and to take care to get the light directly between two of the three prongs, which are somewhat flimsy unless made in thick gauge tubing. My experience is that the image thus seen from a well cut piece of wood is comparable with those shown in the micro-photographs which were taken by transmitted light from specimens carefully cut under the experienced direction of Dr. Wilson, of the Royal Aircraft Factory, and to whom the author is indebted.

At present timber users in the aircraft world do not in general employ any scientific means of identification at all, probably because its importance is not realised. I agree with Professor Boulger that the installation of some apparatus for such work in factories handling work is very desirable.

The Secretary asks whether apple and pear timber could be used in airscrew work.

It is unfortunate that both apple and pear are small trees so that their employment would be practicable only in slow speed, low stressed airscrews, where numerous joints are permissible. This leads us at once to the question of glueing.

These woods appear to take glue fairly well, but I know of no really carefully conducted tests on this important subject, trying the various timbers all with one and the same glue, the joints being made under conditions precisely the same for all. Such a research is badly needed. Summing up this question of apple and pear, I think that as sycamore and beech are preferable, until the supply of these is exhausted apple and pear will probably not be used. Pear is preferable to apple; both are somewhat liable to warp.

The remarks of Professor Somerville are of great interest. No doubt we shall very soon have to take a very serious interest in the subject of Forestry. The appreciation in the value of timber has been enormous since the aircraft industry has grown to such a large size, and the timber supply will be of much greater importance in the future than it has been in the past.

After reading the notes of Mr. Herbert Stone on his key for the identification of timbers, I must say that I look forward to the day when Mr. Stone's table is published. Such a publication would be an important addition to the literature of the English language and to the scientific knowledge of the world.

I am glad that Mr. Lynam has emphasised the existence of false annual rings in certain timbers, as such markings are liable to mislead. His remarks on the identification of mahoganies are valuable.

The conclusion of Mr. H. A. Webb, that the value of E which may be taken when designing struts is higher than that deduced from bending tests made in the ordinary, is an important fact with which I entirely agree.

Major-General RUCK (Chairman of the Aëronautical Society of Great Britain) proposed a hearty vote of thanks to Prof. Groom for presiding, and giving them very interesting information. They could not have had a higher authority on

these matters than Prof. Groom. The Air Ministry was singularly fortunate in getting the benefit of his services during this very trying time. The motion was carried with applause.

On the motion of the CHAIRMAN a vote of thanks was also accorded Mr. Barling.

CONIFERÆ.

The classification of the principal coniferæ may be of interest:—

LARCH (LARIX).

Matures at 40 years.

Larix Lavarica	25 feet	Siberia	—
,, Europea	100 ,,	Europe and Northern Asia	Common larch.
,, Griffithii	40 ,,	Himalayas	Sikkim larch.
,, Leptolepia ...	60 ,,	Japan	Japanese larch.
,, Lyallii	80 ,,	N. America... ...	Mountain larch.
,, Occidentalis ...	250 ,,	N. America... ...	Western tamarack.
,, Pendula	60 ,,	N. America... ...	Black larch or tamarack.

PINE (PINUS).

Matures at 80 years.

Pinus Bungeana ...	50 feet	N. China	Lace bark pine.
,, Cembra	80 ,,	Austria	Stone pine.
,, Coulteri	60 ,,	California	—
,, Excelsa	120 ,,	Himalayas	Bhutan pine.
,, Halepensis ...	40 ,,	Mediterranean ...	Jerusalem pine.
,, Insignis	80 ,,	California	Monterey pine.
,, Laricio	120 ,,	S. Europe	Corsican pine.
,, Laricio Nigricans	80 ,,	N. Europe	Black pine.
,, Monticola ...	100 ,,	B. Columbia ...	Western white pine.
,, Pinaster	80 ,,	Mediterranean ...	Cluster pine.
,, Pinea	50 ,,	Mediterranean ...	Umbrella pine.
,, Ponderosa ...	120 ,,	Pacific Slope ...	Bull pine, yellow pine.
,, Strobus	140 ,,	N. America... ...	Weymouth pine.
,, Sylvestris... ...	80 ,,	N. Europe	Scotch fir.
,, Palustris	80 ,,	N. America... ...	"Long leaf" pine.

SPRUCE (PICEA).

Matures at 80 years.

Picea Ajanensis ...	75 feet	Japan	—
,, Alba	30 ,,	N. America... ...	White spruce.
,, Alcockiana ...	100 ,,	Japan	—
,, Engelmannii ...	100 ,,	B. Columbia ...	—
,, Excelsa	90 ,,	N. Europe	Norway spruce.
,, Morinda	90 ,,	Himalayas	Smith's spruce.
,, Nigra	60 ,,	E. Canada	Black spruce.
,, Orientalis ...	60 ,,	Caucasus	—
,, Pungens	75 ,,	California	—
,, Sitchensis ...	150 ,,	B. Columbia ...	Menzies' spruce.

FIR (ABIES).

Matures at 50 years.

Abies Amabilis ...	120 feet	B. Columbia	...	Red fir.
,, Brachyphylla ...	100 ,,	Japan ...	...	—
,, Bracteata ...	180 ,,	California ...	...	—
,, Cephalonica ...	90 ,,	Greece ...	...	—
,, Concolor ...	120 ,,	Pacific Slope	...	Colorado silver fir.
,, Douglasii ...	200 ,,	B. Columbia	...	Douglas fir.*
,, Forma ...	80 ,,	Japan ...	...	—
,, Fraseri ...	70 ,,	Virginia ...	...	—
,, Grandis ...	180 ,,	Pacific Slope	...	Great silver fir.
,, Cowiana ...	200 ,,	Carolina ...	...	Silver fir.
,, Magnifica...	180 ,,	Oregon ...	...	—
,, Mariesi ...	100 ,,	Japan ...	...	—
,, Nobilis ...	180 ,,	California ...	...	—
,, Nordmanniana ...	90 ,,	Caucasus ...	...	Nordman's fir.
,, Pectinata ...	90 ,,	Italy ...	...	European silver fir.
,, Pinsapo ...	70 ,,	Spain ...	...	—
,, Religiosa ...	70 ,,	Central America	...	—
,, Sachalinensi	170 ,,	Sakhalien ...	...	—
,, Veitchii ...	130 ,,	Japan ...	...	—
,, Webbiana	80 ,,	N. India ...	...	Indian silver fir.
,, Balsamea ...	75 ,,	N. America...	...	Balsam fir.

HEMLOCK (TSUGA).

Matures about 40 years.

Tsuga Mortensiana ...	100 feet	Canada ...	...	Western hemlock.
,, Canadensis ...	80 ,,	Canada ...	...	Hemlock spruce.

REDWOOD (SEQUOIA).

Matures about 500 years.

Sequoia Gigantea ...	300 feet	Pacific Slope	...	Wellingtonia.
,, Sempervivens ...	250 ,,	Pacific Slope	...	Redwood.

The above are the principal timber trees of the narrow-leaved type. The larches are deciduous, the others evergreen. All are reproduced by cones of varying sizes. The heights to which they may be expected to grow, their usual habitat, and any special colloquial name they may be described by are appended.

The hemlocks (except the Douglas fir) are of poor timber and are best described as "pulp wood." The term Oregon pine is a mere trade term and includes Douglas firs (to which it is properly limited), Californian spruce, and other varieties of coniferæ on the Pacific Slope. In North America the fir is often described as a balsam, the Douglas fir being, however, as nearly allied to the spruces as it is to the true firs. The leaves of all these trees are needle-shaped, the differences between the generi being marked by size and shape of cones, and the length and arrangement of the needles.

W. BARNARD FARADAY.

* Also called "Pseudosuga Douglasii," occupies a position allied to both the Balsams and the Hemlocks.

ABSTRACTS.

Speed Meter for Aircraft.

The instrument described is based upon the fundamental equation: Velocity—increment = Acceleration × Time. Acceleration is measured by displacement from zero of a heavy spring-controlled iron sphere. The extent to which this is displaced is made to determine the speed of a wheel which is geared to a recording dial indicating velocity directly. It is absolute speed with regard to the earth which is measured.

The speed of a train is proportional to the speed of the driving wheels which may therefore be used as a measure of train speed. The speed of a ship or aircraft is not proportional to the speed of the propeller and moreover is subject to the effect of currents and wind. Though it is moving forward through the air an aeroplane may be moving backwards with regard to the earth. The true speed with regard to the earth may be determined by measuring the acceleration and allowing for the time that the acceleration is operative.

The mechanism suggested has an iron rod or track laid horizontally and in the direction of the aeroplane's length. On this rod is a heavy iron ball, which is normally held at the centre of the track by a spring at each end of the latter. When the aeroplane is accelerated the iron ball moves backwards from the centre of the track; when the machine is retarded, the iron ball moves forward.

The second part of the mechanism is a horizontal disc rotated at constant speed by clockwork. On this disc rests a small wheel, which is mounted on and can slide along a square shaft. By means of a prong or fork the iron ball moves the small wheel to one side or other of the centre of the rotating disc. The direction of rotation of the small wheel (and of its square shaft) and its speed of rotation are thus determined by the direction and extent of displacement of the iron ball—*i.e.*, by the degree of acceleration or retardation of the aeroplane.

The square shaft is geared to a recording dial, which indicates the net total revolution of the small wheel at any time. This is proportional to the speed of the aeroplane with regard to the earth. The recording dial may be calibrated accordingly. If the instrument is working properly the speed dial comes back to zero at the conclusion of each flight. ("Elektrotechnische Rundschau," April 11th, 1917, Supplement.)

AERONAUTICAL ENGINEERING.

Organised Aeroplane Spruce Production.

This article gives an account of the organisation in the States of Oregon and Washington of the Spruce Production Division of the Signal Corps of the U.S.A. Army for the purpose of obtaining straight-grained spruce suitable for aeroplane construction.

Operations were commenced in October, 1917, when the total production of the numerous companies working independently was 2,000,000 ft. of timber per month. Railway trucks and roads were not in existence, but after four months' working and in spite of labour troubles 87 miles of railroad and truck roads were constructed, sufficient, as estimated, to supply the needs for 18 months to come; also the total production was increased by 500 per cent. with a much reduced cost per thousand feet.

Only 4 per cent. of the spruce timber in the district is suitable for the rigid requirements of straight-grain aeroplane spruce, and it was found advisable to select the trees for felling, to cut them into logs, and to split them before transport. The splitting aided the grading of the timber.

At the commencement of operations 2,000 ft. of timber were required to

make one aeroplane; it now takes 400 ft. Through the work of the traffic department the time taken to move spruce from Oregon and Washington to the Atlantic coast has been reduced from 50 to 10 days, and through the operation of a central cut-up plant at Vancouver, Washington, a saving of 75 per cent. of the number of freight cars, or a total of 3,000 a year, was effected. A technical department in one month increased the production by 11 per cent. as well as improving the specifications.

Oregon and Washington furnish nearly all the aeroplane spruce of the U.S. and its Allies, a small percentage coming from British Columbia, New England, and the south. Sixty per cent. of the produce is taken by the Allies and 40 per cent. by the United States, the total demand being 11,000,000 ft. per month, representing 15 per cent. of the log.

An inventory of the Silka spruce stumpage indicates 11 billion feet of this timber within the spruce belt of the two States, in Alaska 15 to 18 billion, but in the latter case less than a billion are suitable of aeroplane stock. ("Aviation," April 1st, 1918.)

Impregnation of Wings of Aeroplanes.

Quittner and Co., Berlin, advertise "Cellon-emaillit" for the impregnation of the wings of aeroplanes. ("Motorwagen," Jan. 10th, 1918.)

Models of Aeroplanes.

Von Bader, in the "Zeitschrift für Motorluftschiffahrt" (Sept. 29th, 1917), shows that it is possible to use models for testing the constructional strength and stability of aeroplanes. The article contains information regarding the construction of the models required for both purposes, and describes the measurements necessary. ("Zeitschrift des Vereines Deutscher Ingenieure," Nov. 3rd, 1917.)

The Use of Spruce in Aeroplane Construction.

General information is given relative to red, Sitka, and white spruce grown in the U.S.A., the data being obtained by the Forest Products Laboratory of the Forest Service, in charge of J. A. Newlin. The influence of moisture conditions on aeroplane stock, and the relation of density to moisture content, shrinkage, and strength are also considered.

It is stated that spruce of very rapid growth is usually inferior to that of slower growth. Up to about 15 annual growth rings per inch, the greater the number of rings the greater the strength. Wood with less than 8 to 10 rings per inch is usually weak and light.

Contrary to the usual case of timber, spruce is found to show no difference in quality with height in the tree; but the quality varies according to location in the cross section of the tree. Wood immediately surrounding the pith centre is usually light and weak, increasing in strength and density as the distance from the centre increases. The increase in density is not so marked as increase in strength. In trees above medium size neither density nor strength continue to increase with diameter.

The closeness with which the spruces follow the general law of increasing strength with increasing density is shown by curves giving the variation in modulus of rupture and maximum crushing strength with specific gravity. The following relations are given for red, Sitka and white spruces:—

Modulus of rupture, lbs. per sq. inch $= 25{,}000 \sqrt{G^3}$

Maximum crushing strength ,, $= 12{,}000 \sqrt{G^3}$

where G is the specific gravity based on the green volume. The tests were made on small clear specimens tested in a green condition, pieces falling within 3 inches of the pith centre being omitted.

As an instance of the important effect of drying on strength, it is stated that clear green wood having a modulus of rupture 4,500 lbs./sq. in. and a maximum

crushing strength of 2,000 lbs./sq. in. along the grain, would, on drying to the condition of aeroplane stock, increase in these strengths to about 8,000 and 4,000 lbs./sq. in. respectivelv.

At the present time spruce is used too rapidly to permit of long-time storage and air-seasoning under favourable conditions. After the lumber is cut up it is run into conditioning chambers, in which the seasoning of the lumber is hastened. Under these circumstances there is a wide variation of moisture content of machined specimens, observations made at various aeroplane plants indicating that the variation may be as much as 10 per cent. It is thought safe to assume that the better pieces of machined timber will frequently have at least 5 per cent. more moisture than they will ultimately have. A change in moisture content of such magnitude would cause a reduction in tangential dimensions of nearly 2 per cent. and in radial dimensions of 1½ per cent. Since denser specimens generally shrink more than lighter ones, it follows that the rejection of parts because they are slightly under size—except where dimensions are taken immediately after machining—may result in rejection of the higher quality pieces.

Also, since lighter specimens generally dry more quickly than denser specimens, the random selection of pieces for strength tests without reference to moisture content is greatly to be discouraged; 1 per cent. difference in moisture content causes approximately 5 per cent. difference in the crushing strength parallel to the grain. ("Aerial Age Weekly," April 1st, 1918.)

Application of Die-Castings in Aircraft.

Considerable emphasis is laid in this article by Charles Pack, chief chemist and metallurgist of the Doehler Die-Casting Co., on die-casting being essentially a quantity production process.

From his experience, he finds that few parts could be considered practical die-casting propositions in less that 1,000 lots. Where 10,000 or more castings are required the cost of the die is readily absorbed and fades into insignificance. Also, for suitable castings, the author considers that it is essential for success to use a metallic mould capable of withstanding the action of the molten metal and the rapid changes to which it is subjected, to have an appliance specially suitable for delivering the molten metal into the die under pressure sufficient to ensure a casting of perfect contour, and to cast only alloys suitable for this process.

Continuing, attention is drawn to the fact that the advent of the commercial aluminium die-casting at the beginning of the present war increased considerably the number and quantity of allovs available for aircraft work. Apart from accessories, the use of the so-called "Babbitt" metals is referred to, particularly respecting their extended adoption for aero engine bearings. A soft babbitt, it is pointed out, is more likely to squeeze or pound out under pressure due to its low compressive strength, whereas a hard babbitt is likely to crack and crumble under a pound. To overcome this, the so-called babbitt lined bronze back bearing has been developed and is used almost entirely in aero engine construction.

The following bronze back alloys are referred to:—

	Copper.	Zinc.	Tin.	Lead.	Phosphorus.
1	85	5	5	5	—
2	84	2	5	9	—
3	89	—	10	—	1
4	80	—	10	10	—
5	82	—	3	15	—

Of these, the first is an S.A.E. bronze specification, and the second has been found by the author to be the best as far as the actual efficiency of the bearing is concerned.

The importance of a good method of joining the babbitt liner to the bronze shell is referred to and a mechanical bond is not considered to be satisfactory,

especially in connection with the use in actual practice of bronze back bearings in a certain type of 210 h.p. aero engines. Careful soldering is considered to be necessary, and it is pointed out in this connection that "ringing," as a practical test of good workmanship, is not sufficient. For babbitt liners in aeroplane bearings, the following formulæ for alloys are given in the order of the writer's preference:—

	Tin.	Copper.	Antimony.	Nickel.
1	90	4·5	5·5	—
2	89	3·5	7·5	—
3	89	3·0	7·0	1.0
4	84	7.0	9.0	—
5	90	10.0	—	—

The article contains two illustrations, one of a large number of different types of aluminium die-castings and the other of babbitt lined bronze bearings. ("Aviation," April 1st, 1918.)

Properties of Woods Used in Aeroplane Construction.

This article describes the plant and system used at Vancouver Barracks, Portland, Oregon, where the output capacity is 400,000 to 600,000 ft. of aeroplane stock every 24 hours. Great care is taken in the method of cutting to ensure straight grain stock. The following useful table of the properties of various woods is appended, compiled by the Forests Products Laboratory, Madison, Wisconsin:—

	Spruce, Red, White, Sitka, (*Picea Rubens, Canadensis, Sitchensis*).	Pine Western Yellow or Calif. White Pine. (*Pinus Ponderosa*).	Pine Sugar (*Pinus Lambertiana*).	Fir Douglas.
Specific gravity based on volume and weight when oven-dry:				
Average	41	42	39	52
Minimum	36	38	36	47
Weight at 15 per cent. moisture:				
Lbs. per cu. ft.	27	28	27	34
Shrinkage from green to oven-dry condition:				
Radial	3·9	3·9	2.9	5.0
Tangential	7·5	6.4	5.6	7·9
Static bending:				
Fibre stress of elastic limit:				
Lbs. per sq. inch	5,100	6,800	5,300	6,800
Modulus of rupture:				
Lbs. per sq. inch	7,900	8,700	7,400	9,700
Modulus of elasticity:				
1,000 lbs. per sq. inch... ...	1,300	1,300	1,100	1,780
Work to maximum load:				
Inch-lbs. per cubic inch ...	7·4	6.7	5.0	7.2
Compression parallel to grain:				
Max. crushing strength:				
Lbs. per sq. inch	4,300	5,000	4,300	6,000
Compression perpendicular to grain:				
Fibre stress at elastic limit:				
Lbs. per sq. inch	500	640	540	750
Shearing strength parallel to grain:				
Lbs. per sq. inch	920	1,040	950	1,020
Hardness side:				
Load required to imbed 0.444in. ball one half its diameter:				
Lbs.	430	430	410	580

(J. F. Thornel, "Aviation," April, 1918.)

Aeroplane Propellers of Steel and with Variable Pitch.

[Attention should be drawn to the following note on steel and variable pitch propellers, published in some of the American journals.]

"The National Advisory Committee for Aeronautics desires to invite the attention of all designing engineers, and particularly those interested in propeller design, to two very important problems now confronting the air services of the nation, namely, a steel air propeller and a variable pitch air propeller."

The special sub-committee on engineering problems, consisting of Messrs. Durand (chairman), Stratton, Zahm, Dickinson, Chase and Loening, has reported that these problems have been under consideration for some time, but so far without attaining satisfactory results. These problems require careful mathematical study by technicians fully equipped with a sound understanding of the fundamental principle of aeronautical and structural engineering. The ideal variable pitch propeller should embody means for changing simultaneously the diameter, area, and pitch for changes in air density. It is not necessary that the design of a steel propeller should follow the present practice in wooden air propellers, but after careful consideration has been given to the aerodynamical principles involved, design and experimental work should follow fundamental structural engineering practice. The development of such a propeller should be coincident with the development of the variable pitch propeller.

Aeronautical engineers and other technicians are invited to give thought to this problem and submit brief descriptions of their ideas, with such drawings, data, and photographs as are necessary, to the National Advisory Committee for Aeronautics, Munsey Buildings, Washington. ("Society of Automotive Engineers Journal," April, 1918.)

REVIEWS.

How an Aeroplane is Built. By Stephen Blakeney. Introduction by C. G. Grey. London, 1918. The Aeroplane Publishing Company. 8vo., pp. 233. 5s. Illus.

We can give this little volume unqualified praise. It is useful, simple, intelligent, and amusing. The attempt recently made by this Society to interest the thousands of aeroplane workers in their daily toil by means of educational lectures is carried a step further by the issue of volumes like the present. It was said of the late Sylvanus Thompson that he was a profound mathematician because he could explain the differential calculus in language that a child of three could understand, and this book shows a similar merit. Mr. Grey hopes in his introduction that the volume will be appreciated by the factory worker, the draughtsman, the schoolboy, and the merely interested. We echo his hope and think that it will be fulfilled.

RECENT ADDITIONS TO THE LIBRARY.

"How an Aeroplane is Built." By Stephen Blakeney. Introduction by C. G. Grey. London, 1918. The Aeroplane Publishing Company. Illus. 233 pp. oct. 5s.

"Practical Flying." By Flight Commander W. G. McMinnies, R.N. Introduction by Major-General W. S. Brancker, C.M.G. London, 1918. The Temple Press. Illus. Oct., 237 pp. 3s. 9d.

"Winged Warfare." By Major W. A. Bishop, V.C. London, 1918. Hodder and Stoughton. Illus. Oct., 301 pp. 6s.

"The Change in the Climate." By Major R. A. Marriott. London: E. Marlborough. Oct., 94 pp.

"Year Book of Wireless Telegraphy."

"President's Address, Society of British Gas Industries." By Sir Robert Hadfield, F.R.S. London, 1918.